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Agency

Office of Pollution
Prevention and Toxics
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1996 Toxic Release Inventory

Data Quality Report

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EXECUTIVE SUMMARY

As part of a continuing effort to assess and improve the quality of the data contained in the Toxic Release Inventory (TRI) database, the U.S. Environmental Protection Agency (EPA) conducted TRI data quality site surveys for reporting year (RY) 1996. The goals of these site surveys were to:

- Provide a quantitative assessment of the accuracy of TRI data;
- Identify ways to improve the TRI data collection process; and
- Identify where further guidance on the completion of the TRI report forms (EPCRA Section 313 reports) would be beneficial.

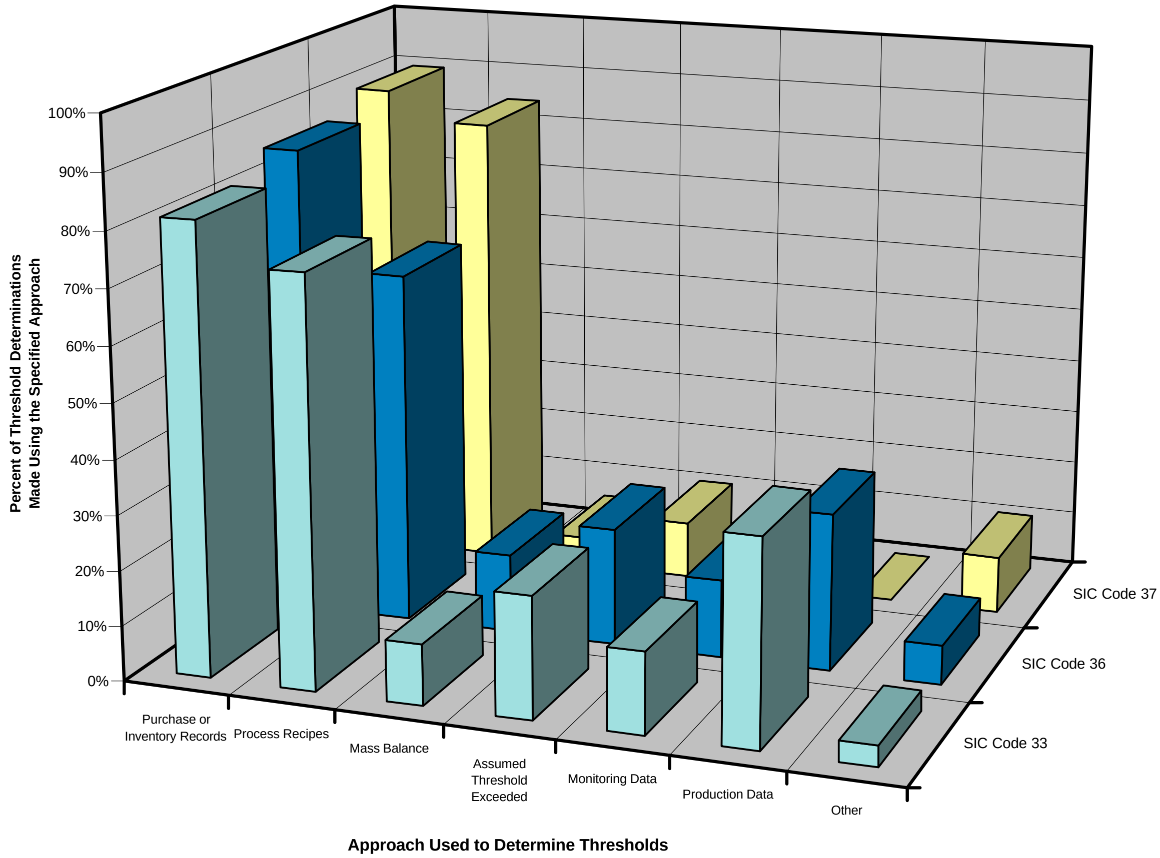
This summary presents the significant findings and conclusions from the site surveys conducted.

This report focuses on surveys completed for RY 1996. Previous reports have presented findings from site surveys for RYs 1987, 1988, 1994, and 1995. For RY 1996, site surveys were completed at 60 facilities:

- 27 facilities in SIC Code 33, the primary metals industry;
- 14 facilities in SIC Code 36, the electronic and other electrical equipment industry; and
- 19 facilities in SIC Code 37, the transportation equipment industry.

Accuracy of TRI Data

Evaluation of the methodologies used by facilities and accuracy of these methods in completing threshold determinations and release and other waste management estimates provide a basis to assess the accuracy of the TRI data. The following information presents the approaches used by facilities and the accuracy of those approaches for completing threshold determinations and release and other waste management estimates.



Information for this figure is discussed in Section 4.2.

Approaches Used by Facilities to Make Threshold Determinations

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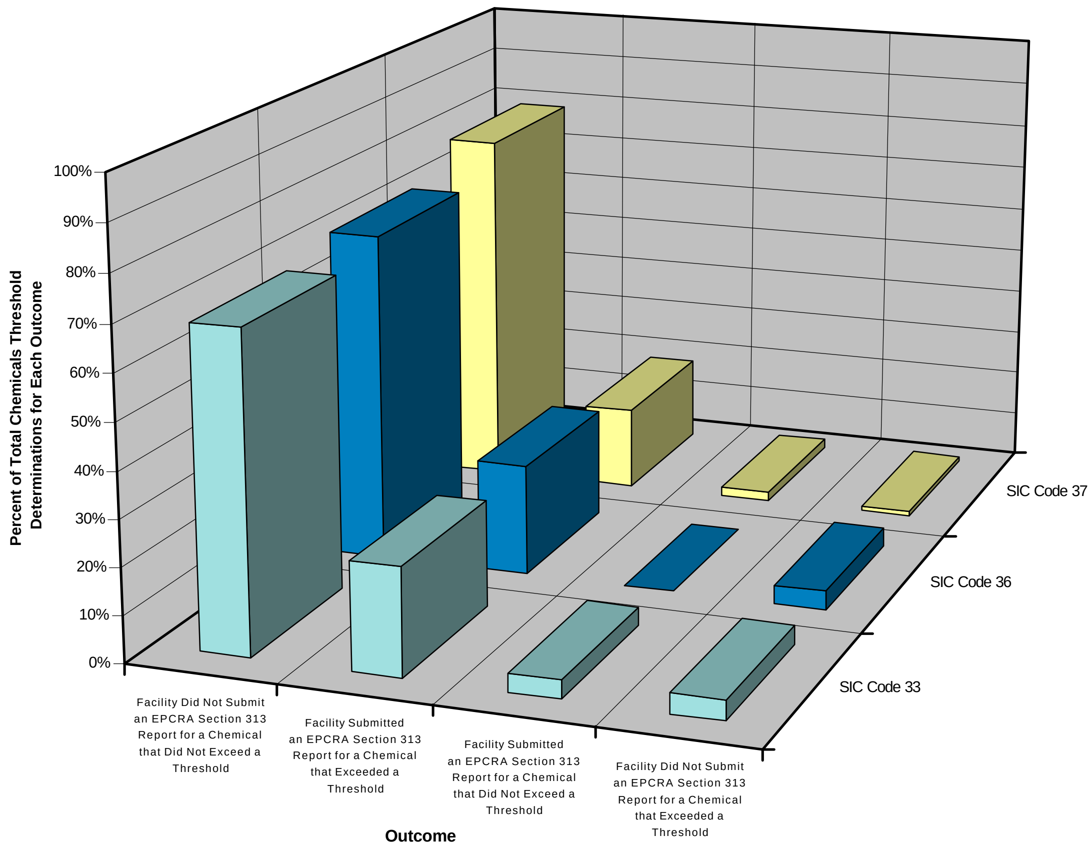
- Facilities primarily use purchase or inventory records, or process recipes to make threshold determinations.

- Facilities in the electronic and other electrical equipment industry (SIC Code 36) and primary metals industry (SIC Code 33) use production data more frequently than those facilities in the transportation equipment industry (SIC Code 37).

- Facilities in the primary metals industry (SIC Code 33) and the electronic and other electrical equipment industry (SIC Code 36) are more likely to assume thresholds are exceeded.



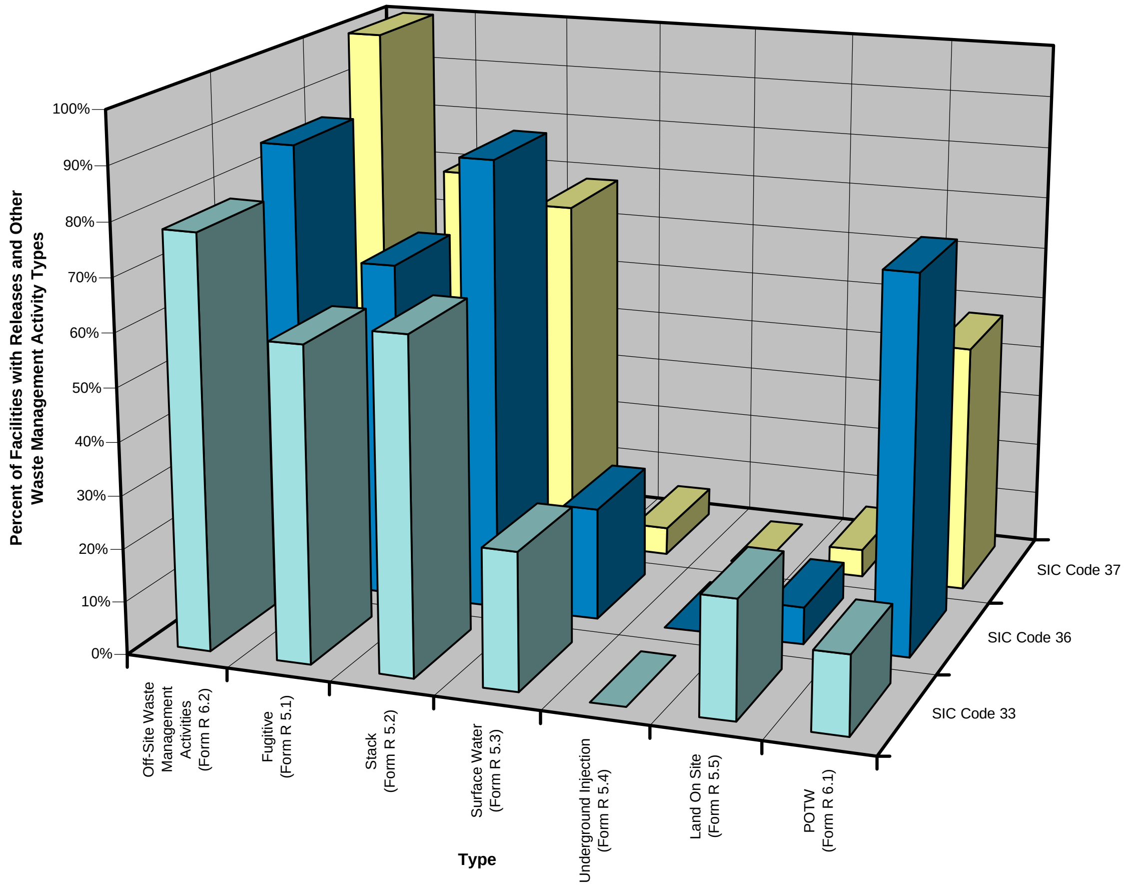
Note: The first tw o outcomes represent cases in w hich facilities correctly determine thresholds, w hile the last tw o outcomes represent cases in w hich facilities incorrectly determine thresholds.

Data for this figure can be found in Table 4-1.

Accuracy of Threshold Determinations

- Considering all EPCRA Section 313 chemicals used on-site, facilities determine thresholds correctly 95% of the time.

- Considering only EPCRA Section 313 chemicals that actually exceeded thresholds, facilities accurately identified the threshold exceedences 88% of the time.



Data for this figure can be found on Table 5-1.

Distribution of Release and Other Waste Management Activity Types

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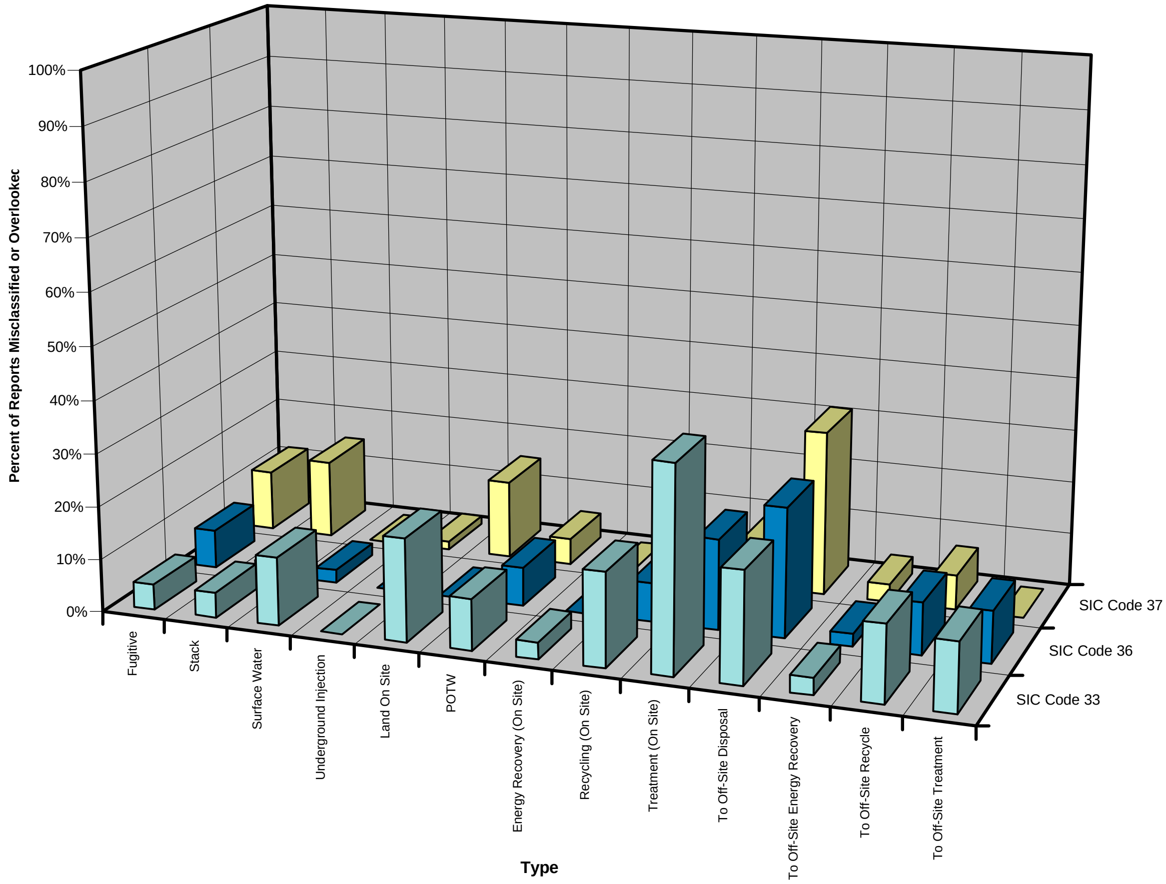
- Fugitive and stack releases and off-site transfers for further waste management activities were observed at most facilities in all industry sectors.

- No facilities in any industry sector visited had on-site underground injection.

- Most facilities in the electronic and other electrical equipment industry (SIC Code 36) had releases to Publicly Owned Treatment Works (POTW)s.



Data for this figure can be found in Table 5-2.

Misclassified and Overlooked Types of Release and Other Waste management Activities

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- Facilities often correctly identified release and other waste management activities that were occurring, but reported them to the wrong type (particularly between stack and fugitive releases and between various off-site transfers for further waste management activities).

- On-site treatment was misclassified or overlooked frequently in the primary metals industry (SIC Code 33) because facilities were confused as to whether air pollution control devices collecting metal should be reported as on-site treatment.

- Recycling, both on and off site, was frequently misclassified due to confusion over the definitions of recycling and reuse.

- Off-site disposal was frequently overlooked at facilities using EPCRA Section 313 Chemicals (typically metals) that were present in dust collected in baghouses, electrostatic precipitators, and rotoclones.

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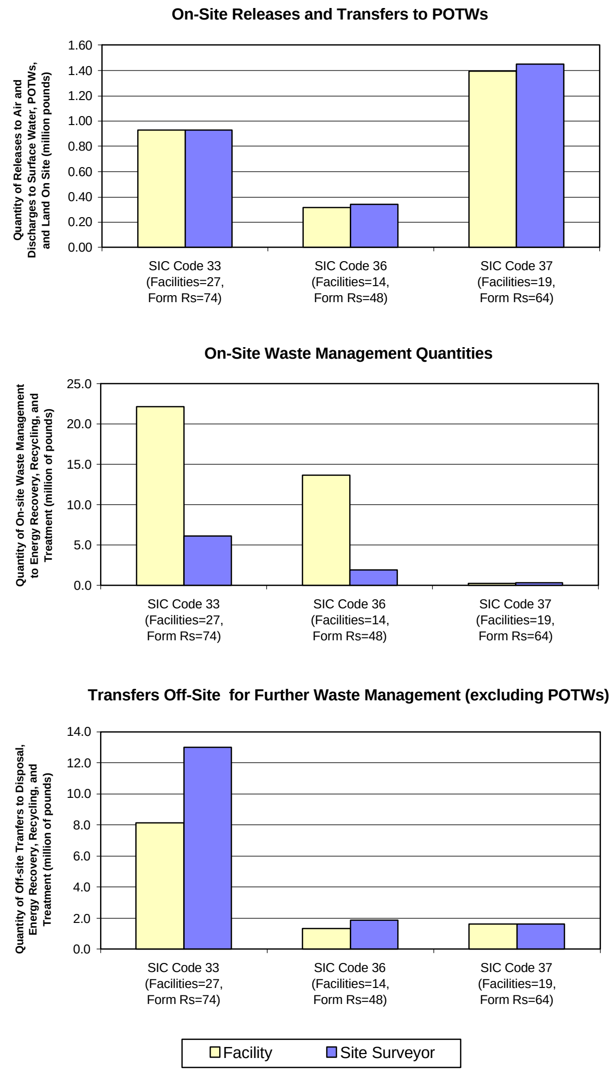


- Facility and site surveyor estimates agreed for the most part for the transportation equipment industry (SIC Code 37).

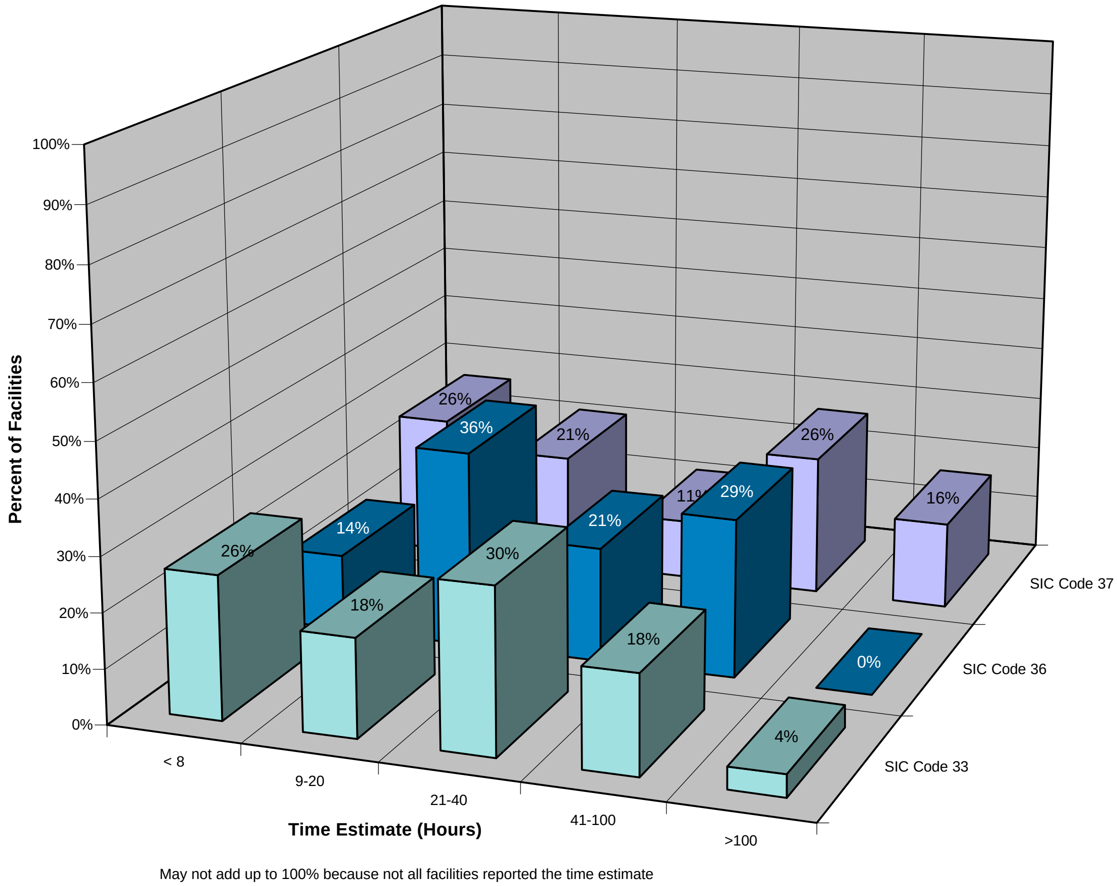
- Facility and site surveyor release and other waste management estimates for the primary metals industry (SIC Code 33) and the electronic and other electrical equipment industry (SIC Code 36) differed significantly, primarily due to the difference in recycling estimates. This difference is attributed to industry confusion over definitions of recycling and reuse.

- Facilities in the primary metals industry (SIC Code 33) processed millions of tons of metals. Thus, the releases, transfers, and other waste management quantities from this industry are much higher than the releases and transfers from the other industries visited.

EXECUTIVE SUMMARY

TRI Data Collection Process

The following section provides a summary of findings on the mechanics of the TRI data collection process. Time required to prepare EPCRA Section 313 reports, feedback on usage of the automated Form R, and usage of the EPCRA Hotline are presented.

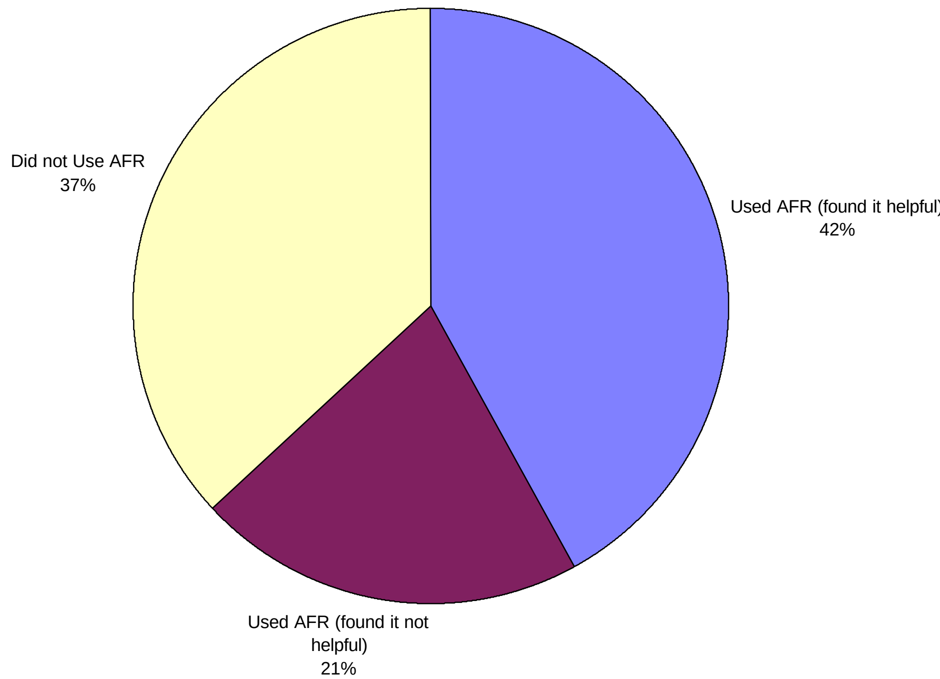


Time Needed to Complete all Form Rs for Facilities Visited in SIC Codes 33, 36, and 37

- The average number of hours to complete each Form R across all three SIC Codes visited is 18 hours, less than the 43 hours per Form R estimated by EPA.

- It takes more time per Form R for a facility to complete one Form R, compared to multiple Form Rs. Facilities filing only one Form R took an average of 22 hours to complete it, while facilities filing more than one Form R took an average of 16 hours per Form R.

EXECUTIVE SUMMARY

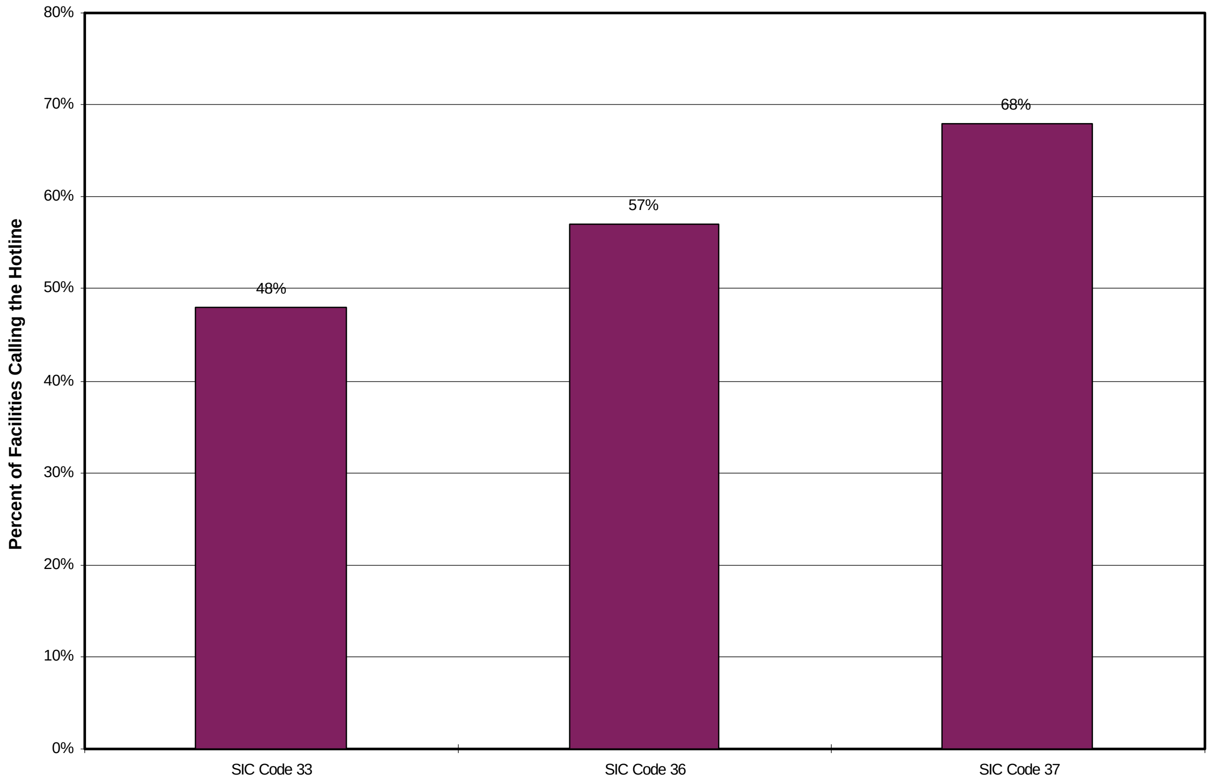


Percent of Facilities Using the Automated Form R

- Of the facilities using the Automated Form R (AFR), approximately two-thirds found it helpful.

- Use of the AFR should eliminate data entry errors and thereby increase the accuracy of data in the TRI database. However, site surveyors found several instances where data listed in the TRI database did not match the AFR submitted by the facility. The nature of these errors should be fixed within the AFR system and corrected.

- Facilities commented that they would use the AFR more often if certain printing problems, computer compatibility issues, and cross-section linkage problems were resolved.



Percent of Facilities Calling the Hotline by Industry

- Facilities in the transportation equipment industry (SIC Code 37) called the hotline 68% of the time, whereas the facilities in SIC Code 36 and SIC Code 33 called the hotline 57% and 48%, respectively. Facilities in the transportation equipment industry also made the least number of incorrect threshold determinations and release and other waste management estimates out of the three industries surveyed. While direct linkage is not certain, this finding suggests that contact with the EPCRA Hotline improves reporting.

Further TRI Guidance

The following section discusses areas where additional instructions or guidance would improve EPCRA Section 313 reporting and increase the accuracy of the TRI database. The areas highlighted in this summary were commonly found in all of the industries surveyed.

Recommendations for Improving Accuracy in in EPCRA Section 313 Reporting

Area for Improvement	Recommendation for Improvement in Future TRI Reporting Years
Overlooked container residue	Instructions and guidance materials should emphasize that even a "RCRA empty" container is expected to contain a residual (possibly up to two inches) and that it must be considered for TRI reporting. Also, note that on-site container rinsing and disposal of the rinsate will result in a water discharge.
Overlooked acid aerosol manufacturing	Instructions and guidance materials should indicate that if H_2SO_4 or HCl is used anywhere in the plant as an aerosol, regardless of whether the process is enclosed or not, their usage should be applied to the threshold determination and release and other waste management calculations.
Incorrectly reporting disposition for off-site transfers	Instructions and guidance materials should emphasize that facilities should attempt to determine the type of receiving facility that is accepting the transfers and exactly how the material sent is being managed (or directly reused) by the receiving facility.
Definitions of recycling versus reuse	Provide a definition of recycling and include examples of streams that can be considered as being recycled in Sections 7 and 8 of the TRI reporting instructions. A good example would be handling of used metals or metal compounds. Specifically, a discussion of what waste management activity must be applied to a used metal for it to be considered recycled versus reused, would be helpful.
Definitions of source reduction	Consider shortening the list of codes for source reduction and providing definitions for each code.

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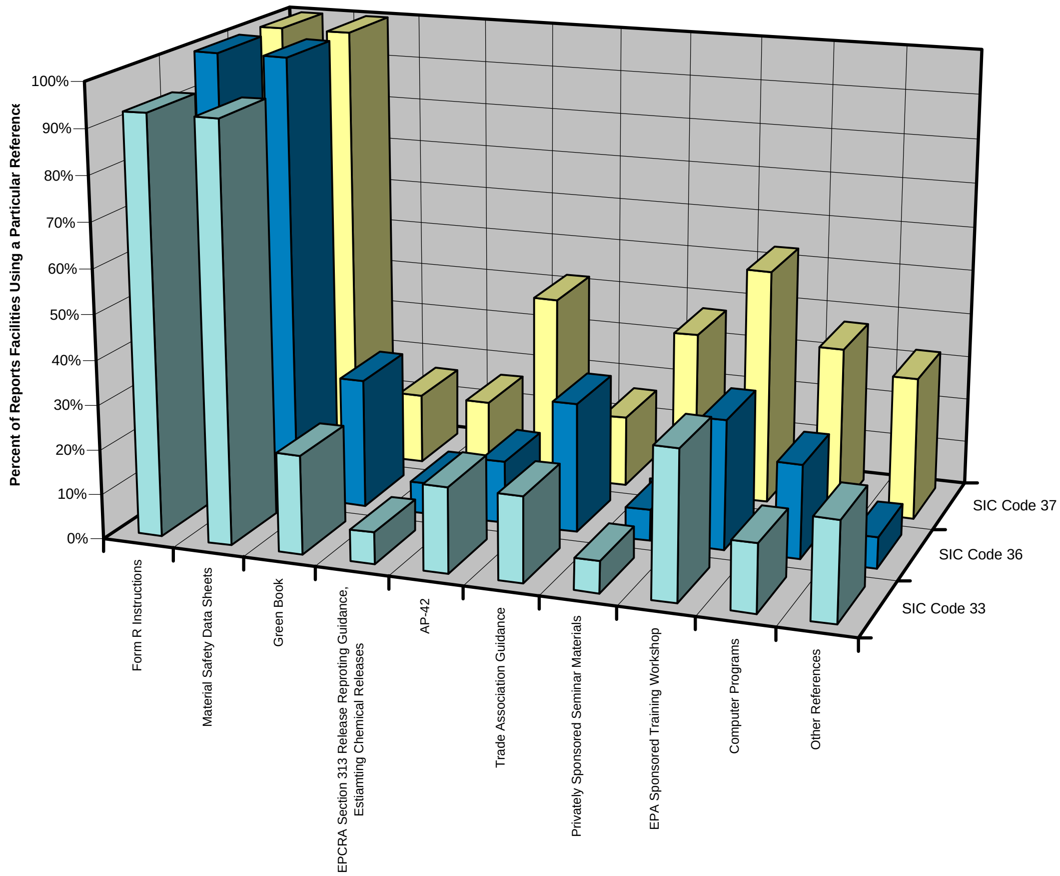
Area for Improvement	Recommendation for Improvement in Future TRI Reporting Years
Clarification of on-site treatment of waste streams containing metals	Provide clarification of on-site treatment definitions pertaining to waste streams containing metals. Guidance is needed to instruct how to report collection of metals in an air pollution control device, whether a treatment efficiency or collection efficiency should be reported in Section 7A, and what to put in Section 8 of the Form R in this scenario.
Clarification of the treatment definitions in Sections 7 and 8 of the Form R for organic and inorganic chemicals. Section 7A applies to the waste stream containing the toxic chemical while Section 8 applies to the toxic chemical itself. These differences have caused confusion when reporting. Confusion occurs when chemicals go through a treatment system but are not destroyed.	Facilities need direct guidance in the TRI reporting instructions to claim zero efficiency, and then what to put in Section 8 (zero or NA).

Evaluation of common references used and the percentage of facilities that attended EPA training workshops assists in characterizing the usage of existing support materials for TRI reporting. The following illustrates the level of usage of support materials.



Common References Used to Compile Form Rs for RY 1996

- Most facilities surveyed use the Form R instructions and material safety data sheets as their main references in compiling Form Rs.

- Over half of the facilities visited in the transportation equipment industry (SIC Code 37) attended EPA-sponsored training workshops. It is noteworthy that threshold determinations and release and other waste management estimates in this sector were the most accurate of the industry sectors surveyed.

- Many facility contacts and a trade association representative in the primary metals industry (SIC Code 33) requested that EPA sponsor a training workshop specifically for their industry. In addition, facility contacts expressed an interest in a TRI guidance document specific to foundry operations, and another document specific to reporting for metals. Such efforts would improve accuracy, particularly if focused on metal versus metal compounds, *de minimus* applicability, the definitions of recycling versus reuse, and the reporting of metals collection/treatment.

1.0 INTRODUCTION

Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) requires the U.S. Environmental Protection Agency (EPA) to collect information from manufacturers, processors, and users of listed toxic chemicals on release and other waste management activities of those chemicals to the environment. To collect such information, EPCRA requires that EPA implements a yearly reporting requirement from such facilities. EPCRA Section 313 reports, referred to as Form R/A reports, are due to EPA by July 1 each year to fulfill the reporting requirement for the previous calendar year. The reporting requirement was first implemented for the 1987 calendar year. The data from the Form R chemical reports are compiled in EPA's Toxics Release Inventory (TRI) database for future analysis, distribution, and evaluation. TRI data, as mandated by EPCRA, are made available to the public. The information collected under EPCRA Section 313 is useful in helping inform the general public and the communities surrounding affected facilities of release and other waste management activities of toxic chemicals, assisting the Agency to focus their research into the effects and control of toxic substances, and aiding in the development of regulations, guidelines, and standards.

The study discussed in this report reviewed data from the 1996 reporting year (RY 1996) to provide a quantitative assessment of the accuracy of the data collected, to identify areas in the TRI data collection process that could be improved, and to disseminate further guidance on the completion of EPCRA Section 313 reports.

The study was conducted by performing on-site surveys of TRI information at 60 randomly chosen facilities:

- 27 facilities in SIC Code 33, primary metals industry;
- 14 facilities in SIC Code 36, electronic and other electrical equipment industry; and
- 19 facilities in SIC Code 37, transportation equipment industry.

This report presents the data gathered for RY 1996 and compares it to data from similar studies completed for previous reporting years, where appropriate.

This data quality report is organized as follows:

- **Section 1** - Introduction, including site survey objectives;
- **Section 2** - Sample selection and approach;
- **Section 3** - Description of industrial processes surveyed;
- **Section 4** - Threshold determinations made by the facilities;
- **Section 5** - Sources and types of release and other waste management activities;
- **Section 6** - Quantity of release and other waste management activities;
- **Section 7** - Preparation of the Form R; and
- **Section 8** - Conclusions and recommendations.

1.1 EPA's Overall Quality Assurance Program

Because of the wide audience and many intended uses of the TRI data, EPA designed and implemented a program to assess the quality of the data collected under EPCRA Section 313 and to identify areas where better guidance materials would be useful for improving the accuracy of future reported data. The site surveys described in this report are a component of EPA's overall quality assurance program.

1.2 Site Survey Objectives

EPA's site surveys were designed to provide a quantitative assessment of the accuracy of the data submitted for a calendar year by identifying the frequency and the magnitude of errors in the Form R data and the reasons these errors occurred. EPA believed that on-site review of industrial processes, pollution control technologies, and documentation supporting the Form R reports would reveal errors in the database not obvious from review of a facility's Form R submissions. Expected error types included overlooked chemicals, incorrectly included chemicals, and errors in the release and other waste management quantity estimate calculations. The goal of the surveys was to obtain information that could be used to improve the Form R reporting instructions and definitions, and associated guidance materials, and thus improve the quality of data in the TRI database in future years.

Anyone who uses the results of the site survey program, as well as the TRI database itself, should be aware of a basic limitation of the EPCRA reporting process. Under EPCRA, facilities are not required to perform any additional monitoring or measurement of the quantity of toxic chemicals released to the environment to calculate Form R release and other waste management quantity estimates. Therefore, the methods selected by facilities to estimate release and other waste management quantities depend on the nature of the best readily available data. The accuracy of release and other waste management quantity information reported to EPCRA therefore depends on the accuracy of the best readily available data and any subsequent estimation methodologies.

At facilities where supporting data were available, site surveyors carefully examined the facility's estimation calculations and data sources and then recalculated the estimates. In many instances, the site surveyors were able to identify data sources overlooked by facility personnel. These new data were then used to recalculate release and other waste management quantity estimates during the site visits. However, site surveyors did not conduct any monitoring or measurements during the site visits. Site surveyors also assessed the quality of the estimation methods by recalculating release and other waste management quantities using alternative approaches where more accurate estimation methods were appropriate or where available data warranted the use of alternative approaches.

1.3 Prior Site Survey Efforts

EPA has conducted five sets of quality assurance site surveys since the first submittal of Form Rs from industry. The RY 1987 site surveys covered all SIC Codes affected by the EPCRA Section 313 requirements. The RY 1988 site surveys covered SIC Codes 28, 291, and 34 - 38. The RY 1994 site surveys covered SIC Codes 25, 281, 285, and 30; RY 1995 site surveys covered SIC Codes 26 and 286.

The results of the site surveys help EPA identify ways additional guidance can be structured to improve the overall quality of the data generated under EPCRA reporting.

2.0 APPROACH

The RY 1996 site survey program was conducted using the following steps:

(1) Revising the survey instrument;
(2) Selecting facilities to be visited (Sample selection);
(3) Training site surveyors (Training);
(4) Arranging site visits;
(5) Performing site visits (Site visit methodology);
(6) Data management and data quality assurance; and
(7) Data analysis and reporting.

This approach is presented schematically in Figure 2-1, and each of these steps is discussed in the following subsections. The approach was originally established for the RY 1987 and RY 1988 site survey programs to ensure consistency in conducting site surveys and accuracy of the results. It was improved for each of the RY 1994, RY 1995, and RY 1996 site survey programs based on experience and lessons learned from the previous programs.

2.1 Survey Instrument

The survey instrument, shown in Appendix A, was designed to standardize and facilitate the review of threshold determinations, and the calculations used to assess release and other waste management activities at facilities. The engineers and scientists who performed the site surveys used the survey instrument as a detailed checklist to ensure that all pertinent items were reviewed. The survey instrument also provided a consistent format for recording both the data collected during site surveys and the errors made by facility personnel on their Form R reports.

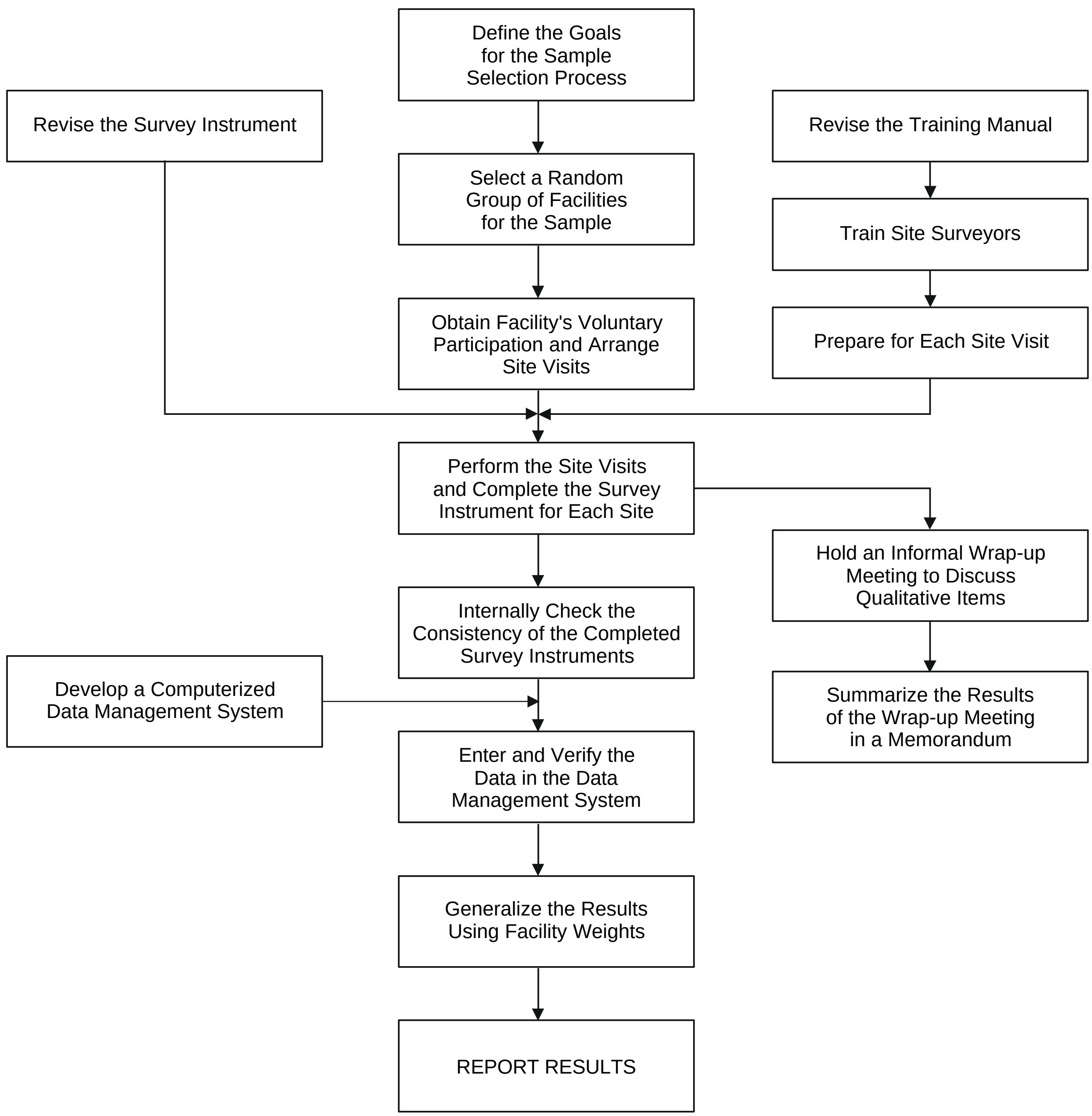


Figure 2-1. Approach Used to Perform the RY 1996 EPCRA Section 313 Site Survey Program

In addition to its primary focus on chemical-specific information, the survey instrument contains questions regarding the usefulness of the reporting instructions, EPCRA Section 313 hotline, and the other published guidance materials. Each section of the survey instrument focuses on identifying specific types of errors made by facility personnel on their Form R submittals.

The RY 1996 data quality site surveyors used a revised version of the survey instrument from previous site survey programs. Most of the questions remained the same, but some additional questions concerning available documentation, possible sources for threshold determinations, source reduction activities, pollution prevention technology, and use of the Form A were added to clarify information received during the site visits and to assess the usefulness of the new guidance and materials that are now available. The increments for amount of time needed to complete all Form Rs at the facility were adjusted slightly in the RY 1996 survey instrument to obtain a more precise estimate of time needed. The format was also revised to make the survey instrument easier for the site surveyors to use.

2.2 Sample Selection

For RY 1996, a total of approximately 64,000 Form R reports and 7,000 alternate threshold certification statements, referred to as Form A reports, covering all SIC Codes required to report toxic chemicals, were submitted to EPA by approximately 22,000 facilities and entered into the TRI database. At the time the site surveys for RY 1996 were conducted, the following number of Form Rs and Form As had been submitted and incorporated in the TRI database for the selected SIC Codes:

SIC Code	Number of Facilities	Number of Form Rs	Number of Form As
33	1,902	6,138	465
36	1,233	3,031	90
37	1,248	4,117	214

The primary objective of the sample selection approach was to obtain a random group of facilities from the key industry groups within the specific SIC Codes being surveyed to scale up appropriately the results to reflect the reporting of the entire SIC Code group. The RY 1996 site visit program targeted 60 completed site visits at facilities in SIC Codes 33, 36, and 37. These SIC Codes represent the primary metal industries, electronic and other electrical equipment and components, and transportation equipment, respectively. The SIC Codes ultimately visited were further defined as the three-digit SIC Codes 331, 332, 333, 334, 335, 367, 369, 371, and 372. The other three-digit codes within SIC Codes 33, 36, and 37 were not targeted by the survey so as to increase the confidence level of the sample by decreasing the target population size. The three-digit codes selected have the most Form Rs and facilities within the targeted two-digit SIC Code.

The number of facilities visited in each three-digit SIC Code was based on a statistical weighting technique, calculated as the product of the total number of targeted facilities (60) and the percentage of facilities in each three-digit SIC Code (with respect to the total number of facilities in all the three-digit SIC Codes listed above). The table below shows the number of facilities visited within each three-digit SIC Code.

SIC Code	SIC Description	Number of Facilities Visited
331	Steel works, blast furnaces, and rolling and finishing mills	8
332	Iron and steel foundries	7
333	Primary smelting, refining of nonferrous metals	1
334	Secondary smelting, refining of nonferrous metals	3
335	Rolling, drawing, extruding of nonferrous metals	8
367	Electronic components and accessories	11
369	Miscellaneous electrical machinery, equipment, and supplies	3
371	Motor vehicles and equipment	15
372	Aircraft and parts	4

Only facilities with 15 or fewer Form Rs were considered candidates for site visits due to time and budget considerations. Site visits to facilities with more than 15 Form Rs would have taken considerable time, and would have limited the total number of facilities that could be visited. Since the same facility personnel may complete multiple reports at a given facility, visiting more facilities gives a better indication of the range of reporting practices.

2.3 Site Surveyor Selection and Training

The engineers and scientists who staffed the site survey program were selected on the basis of their experience in performing environmental audits of industrial processing facilities, and thus were required to have a thorough understanding of chemistry, technical calculations, multimedia environmental concerns, and pollution control technologies.

A surveyor training program was developed to ensure consistency and high quality work among all site surveyors. The training program consisted of three steps:

1) Compiling a comprehensive training manual, including copies of EPA guidance documents and other references;

2) Holding training sessions to familiarize project personnel with program requirements; and

3) Conducting standardized reviews of the completed survey instruments with feedback to the site surveyor to maintain a consistent approach among all surveyors.

2.4 Arranging Site Visits

The goal in arranging site visits was to provide each facility in the sample with an equal opportunity to participate in the site visit program. Participation was voluntary; the facilities were not legally required to participate. A key factor encouraging voluntary participation was the assurance that the facilities would remain anonymous. Names, location, and all other facility identification data are shielded from EPA. Upon facility request, the contractors performing the site visits signed a written confidentiality agreement.

As a first step, introduction letters were sent to each facility's technical contact, and where appropriate, to each facility's senior management official (a sample of a letter is provided in Appendix B). This letter explained the purpose of the quality assessment program and the anticipated burden and benefits to the facility. They also provided assurance to the facility that all facility-specific data would be treated as confidential. EPA's contractors then called the technical contacts at the facilities to solicit their participation, to arrange a date for the site visit, and to review a preliminary agenda for the site visit.

2.5 Conducting Site Visits

The goal of the site visit was to collect all the information needed to complete the survey instrument accurately, while minimizing burdens on facility staff. On-site survey activities included tours of the facilities, which focused on material storage areas, industrial processing operations, and pollution control equipment; careful review of all readily available documentation, which could include MSDSs, production data, monitoring data, purchasing records, and facility spreadsheets or computer software with this information; and interviews with appropriate facility employees regarding documentation materials. Site surveyors did not perform any monitoring or measurements during the site visits.

The site visits were designed to determine:

- Overlooked chemicals;
- Release and other waste management activities;
- Errors in the Form R reports submitted to EPA;
- Whether more accurate release estimation methods could have been used, based on information available to the facilities; and
- Whether further EPA guidance is needed on certain issues for that particular industry.

Release and other waste management estimates were recalculated or recreated by site surveyors from available documentation during the visit. Site surveyors recorded these results on the survey instrument and reviewed the results with facility personnel before leaving the site. Site surveyors held a wrap-up meeting at the facility with the person who filled out the Form R reports at the end of the visit to discuss the facility contact's issues or questions and to review the conclusions and recommendations of the site surveyor. Site surveyors may have called the facility contact after the on-site visit occurred to discuss any remaining issues that required clarification or additional research.

2.5.1 Data Collection

Site surveyors reviewed 191 Form R chemical reports and 605 additional chemicals with amounts used or activities that did not meet the reporting criteria at the 60 facilities visited for RY 1996. Site surveyors reviewed threshold determinations, and release and other waste management estimates separately to identify the frequency, magnitude, and sources of errors in these areas. Site surveyors followed the steps described in the Form R reporting instructions for completing threshold determinations and release and other waste management estimates. The Form R reporting instructions state that facilities must first assess which chemicals are manufactured, processed, or otherwise used in excess of appropriate thresholds. Facilities must then estimate and report all release and other waste management quantities of listed chemicals exceeding thresholds.

2.5.2 Threshold Determinations

Facilities may make the following types of errors in determining which chemicals at their site meet a EPCRA Section 313 thresholds:

- Overlooking a chemical;
- Incorrectly calculating a threshold amount;
- Incorrectly applying *de minimus* exclusions;
- Incorrectly applying an exemption; and
- Misclassifying a chemical activity.

To identify errors in threshold determinations, site surveyors looked for problems in a facility's documentation. On the plant tour, site surveyors looked for evidence of chemicals that were reported but should not have been reported, and for evidence of chemicals that were not reported but should have been reported. The site surveyors reviewed each facility's documentation to track the decision process used to determine whether a chemical should have been reported. Furthermore, site surveyors used all available documentation to recalculate threshold estimates for reported chemicals and for chemicals present but not reported to verify the accuracy of facility calculations.

2.5.3 Release and Other Waste Management Estimates

Facilities most commonly make the following types of errors in calculating release and other waste management estimates for EPCRA Section 313 chemicals:

- Overlooking a chemical;
- Overlooking a source of data;
- Incorrectly calculating a release or other waste management quantity; and
- Incorrectly interpreting the reporting instructions.

During the site survey program, site surveyors used a two-part approach to identify facility errors in estimating release and other waste management activities. First, site surveyors always recalculated release and other waste management quantities using the same technical approach used by the facility. Second, whenever the site surveyor's experience and training indicated that a calculation approach different than the one used by the facility was appropriate, the surveyor attempted to obtain the data needed to calculate release and other waste management quantities using the more appropriate approach. In many such instances, data were not readily available during the site visit to recalculate these amounts using the alternative approach. In the cases where site surveyors were able to recalculate release and other waste management amounts using alternative approaches, they were able to assess the reasonableness of the estimation techniques used by facility personnel.

The surveyors quantified all numerical differences between the facility's estimates and the recalculated values, even in instances where surveyors identified only small differences. As discussed later, these numerical differences were used to assess quantitatively the accuracy of the total aggregate release and other waste management quantities contained in the TRI database.

2.6 Data Management/Data Quality Assurance

Many steps were taken to ensure the data quality of the surveyor's estimates and to verify the data in the survey database. This section outlines the procedures used to review the survey instruments after they were completed by the site surveyor, the database system, and the data entry into the master database; describes the verification procedures for the data entered into the database; presents the data weighting used to apply the results to the entire population of facilities for each SIC Code surveyed; and discusses potential sources of error in the site survey program.

2.6.1 Quality Review of Survey Instrument and Data Entry

All survey instruments were reviewed twice by a set of reviewers to ensure site survey calculations and methodologies used were correct and consistent for all site surveys. All data were double entered into the database, compared to each other, and then verified with the actual survey if an inconsistency was found. Project staff also reviewed the database entries for internal consistency and completeness by comparing responses to various questions as appropriate.

2.6.2 Data Weighting

To allow EPA to compare the site survey program results to the TRI database for the SIC Codes surveyed, weighting factors were applied to the site visit data. These factors or "weights" represent the number of facilities in the TRI database represented by each of the surveyed facilities. Each facility was randomly selected and the number of facilities chosen from each three-digit SIC Code was proportional to the percentage of facilities in any three-digit SIC Code; therefore, each facility was weighted equally.

The sample facilities weights in each SIC Code group are summed to represent the total population of facilities included in the TRI database for that SIC Code group. A total population of 1,492 facilities for SIC Code 33 (covering SIC Codes 331, 332, 333, 334, and 335), 781 facilities for SIC Code 36 (covering SIC Codes 367 and 369), and 1,034 facilities for SIC Code 37 (covering SIC Codes 371 and 372) represents the TRI data for RY 1996.

2.6.3 Limitations of the Analysis

The design and implementation of the survey may have introduced unavoidable inaccuracies in the study results. The three primary sources of error are:

- Sample selection bias;
- Survey implementation; and
- Data reduction and analysis.

The relatively small number of facilities sampled introduced a sample selection bias. The smaller the number of facilities sampled, the greater the likelihood that these facilities do not accurately represent the universe of reporting facilities. For the selected sample size of 60 facilities in SIC Codes 33, 36, and 37, the 90% confidence interval is plus or minus 11%. That is to say, if 50% of the visited facilities reported accurate data, a 90% probability exists that between 39% and 61% of the facilities in the national database reported accurate data.

Another possible source of error concerns the fact that approximately 15 different surveyors performed the survey. This source of inaccuracy was controlled to the extent possible by the use of a carefully designed survey instrument and extensive quality assurance provisions. Nevertheless, it is possible that different surveyors made different judgments in the course of the site surveys.

Finally, certain assumptions were made to simplify data analysis. The key assumption was that the facilities and Form Rs examined in the site visits accurately represent all facilities in their SIC Code group in terms of the accuracy of the data submitted. Aside from possible errors introduced by the relatively small size of the sample, the sampled facilities may not fully represent their SIC Code group because the sampled facilities excluded any facility with more than 15 Form Rs for budgetary reasons. In addition, we have observed that, in general, facilities that volunteer to participate in the program are smaller in size and have less throughput than facilities that decline to participate. To the extent that facilities submitting more than 15 Form Rs or larger facilities with more throughput report more (or less) accurate data than the sampled facilities, the facilities sampled may not fully reflect the universe of facilities in the database.

2.7 Data Analysis and Reporting

Once the results of the site surveys were loaded into a database and the database was validated through the quality assurance process described above, the data were evaluated to discern trends in the quality of data in the TRI forms. The results of that analysis are presented in the following sections.

3.0 DESCRIPTION OF INDUSTRIAL PROCESSES SURVEYED

This section describes the major industrial processes seen on the site visits in SIC Codes 33, 36, and 37. The manufacturing processes described include:

- Iron and Steel Manufacturing at facilities in SIC Code 33 (Section 3.1);
- Primary aluminum processing at facilities in SIC Code 33 (Section 3.2);
- Primary zinc processing at facilities in SIC Code 33 (Section 3.3);
- Semiconductor manufacturing at facilities in SIC Code 36 (Section 3.4);
- Printed board manufacturing at facilities in SIC Code 36 (Section 3.5);
- Motor vehicle equipment manufacturing at facilities in SIC Code 37 (Section 3.6); and
- Motor vehicle painting/finishing at facilities in SIC Code 37 (Section 3.7).

The section is designed to provide a general understanding of the industries surveyed, and to provide an overview of the inter-relationship between the industrial process, pollutant outputs, and pollution prevention opportunities within those industries.

This section specifically contains a description of commonly used production processes, associated raw materials, the byproducts produced, and the materials either recycled or transferred off-site for further waste management. This discussion, coupled with schematic drawings of the identified processes, provides a concise description of where wastes may be produced in the process. This section also describes the potential fate (air, water, land) of these waste products.

3.1 Iron and Steel Manufacturing and Processing

Steel is an alloy of iron usually containing less than one percent carbon. Steel production occurs in several sequential steps as shown in Figure 3-1. The two types of steelmaking technology in use today are the basic oxygen furnace (BOF) and the electric arc furnace (EAF). Although these two technologies use different input materials, the output for both furnace types is molten steel which is subsequently formed into steel mill products. The BOF input materials are molten iron, scrap, and oxygen. In the EAF, electricity and scrap are the input materials used. BOFs are typically used for high tonnage production of carbon steels, while EAFs are used to produce carbon steels and low tonnage alloy and specialty steels. The processes leading up to steelmaking in a BOF are very different than the steps preceding steelmaking in an EAF; the steps after each of these processes used to turn molten steel into steel mill products are the same.

3.1.1 Steelmaking Using the Basic Oxygen Furnace

The process of making steel in a BOF is preceded by cokemaking and ironmaking operations. In cokemaking, coke is produced from coal. In ironmaking, molten iron is produced from iron ore and coke. Each of these processes and the subsequent steelmaking process in the BOF are described below. Figure 3-1 shows the process overview of steelmaking using a BOF.

3.1.1.1 Cokemaking

Coal processing in the iron and steel industry typically involves producing coke, coke gas, and by-product chemicals from compounds released from the coal during the cokemaking process as shown in Figure 3-2. Coke is carbon-rich and is used as a carbon source and fuel to heat and melt iron ore in ironmaking. In cokemaking, pulverized coal is heated at high temperatures in the absence of air in batteries of ovens. Volatile byproducts are collected and processed for other uses. The solid carbon remaining in the oven (coke) is then processed for ironmaking. The necessary heat for coke distillation is supplied by external combustion of fuels (e.g., recovered coke oven gas, blast furnace gas) through flues located between ovens. At the end of the heating cycle, the coke is pushed from the oven into a rail quench car. The quench car takes it to the quench tower, where the hot coke is cooled with a water spray. The coke is then screened and sent to the blast furnace or to storage.

In the by-products recovery process, volatile components of the coke oven gas stream are recovered including the coke oven gas itself (which is used as a fuel for the coke oven), naphthalene, ammonium compounds, crude light oils, sulfur compounds, and coke breeze (coke fines). During the coke quenching, handling, and screening operation, coke breeze is produced. Typically, the coke breeze is reused in other manufacturing processes on-site (e.g., sintering) or sold off-site as a by-product.

3.1.1.2 Ironmaking

In the blast furnace, molten iron is produced, as shown in Figure 3-2. Iron ore, coke, and limestone are fed into the top of the blast furnace. Heated air is forced into the bottom of the furnace. The carbon monoxide from the burning of the coke reduces iron ore to iron. The acid part of the ores reacts with the limestone to create a slag which is drawn periodically from the furnace. This slag contains unwanted impurities in the ore. When the furnace is tapped, iron is removed through one set of runners and molten slag via another. The molten iron is tapped into refractory-lined cars for transport to the steelmaking furnaces. Residuals from the process are mainly sulfur dioxide or hydrogen sulfide, which are driven off from the hot slag. The slag is the largest by-product generated from the ironmaking process and is reused extensively in the construction industry. Blast furnace flue gas is cleaned and used to generate steam to preheat the air coming into the furnace, or it may be used to supply heat to other plant processes. The cleaning of the gas may generate air pollution control dust in removing coarse particulates (which may be reused in the sintering plant or landfilled), and water treatment plant sludge in removing fine particulates by venturi scrubbers.

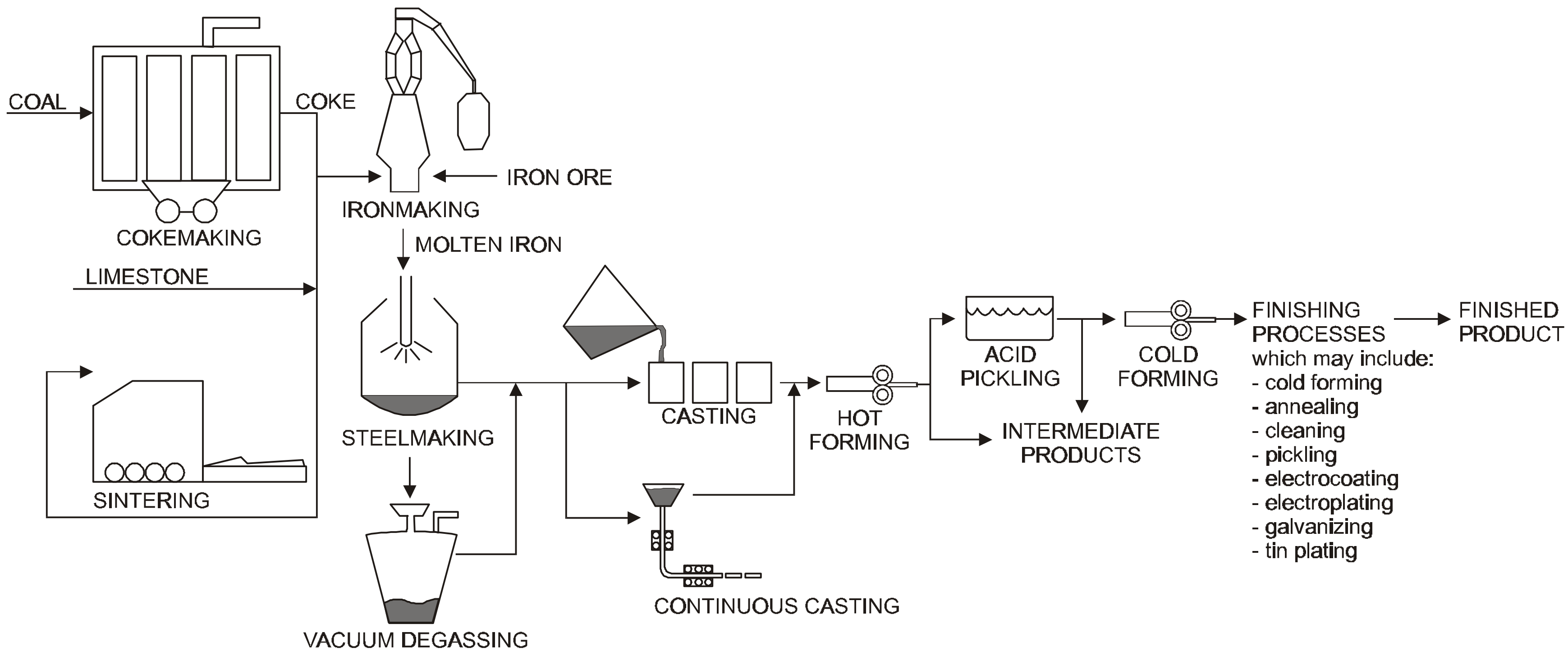


Figure 3-1. Iron and Steel Manufacturing Process Overview Using a BOF

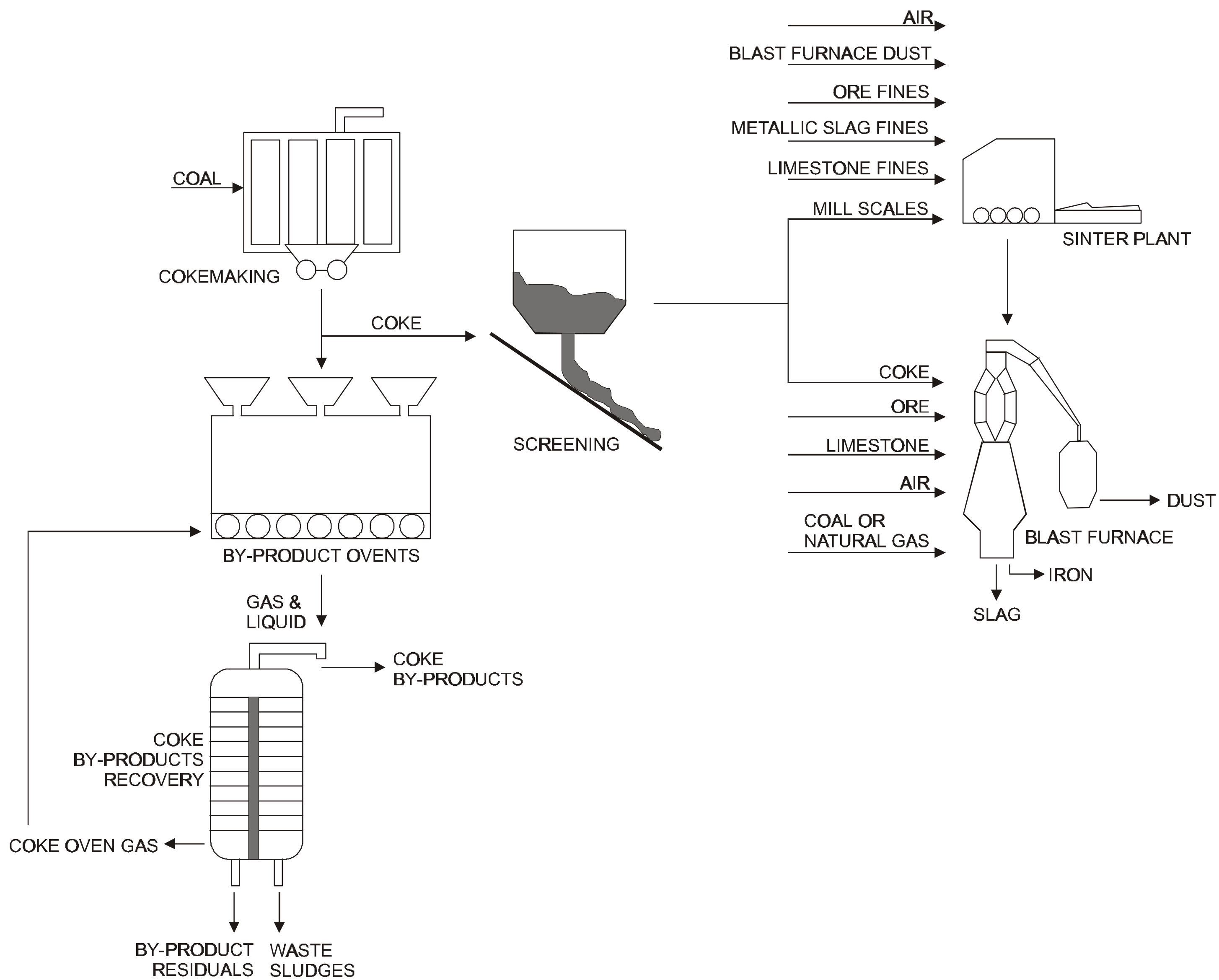


Figure 3-2. Iron and Steel Manufacturing Cokemaking and Iron Making

3.1.1.3 Sintering

Sintering is the process that agglomerates fines (including iron ore fines, pollution control dusts, coke breeze, water treatment plant sludge, and flux) into a porous mass for charging to the blast furnace. Through sintering operations, a mill can recycle iron-rich material, such as mill scale and processed slag. Not all mills have sintering capabilities. The input materials are mixed together, placed on a slow-moving grates and ignited. Windboxes under the grate draw air through the materials to deepen the combustion throughout the traveling length of the grate. The coke breeze provides the carbon source for sustaining the controlled combustion. In the process, the fine materials are fused into the sinter agglomerates, which can be reintroduced into the blast furnace along with ore. Air pollution control equipment removes the particulate matter generated during the thermal fusing process. If electrostatic precipitators or baghouses are used as the air pollution control equipment, the dry particulates captured are typically recycled as sinter feedstock, or are landfilled as solid waste.

3.1.1.4 Steelmaking

In a batch mode, molten iron from the blast furnace, flux, alloy materials, and scrap are placed in the BOF, melted and refined by injecting high-purity oxygen. A chemical reaction occurs, where the oxygen reacts with carbon and silicon generating the heat necessary to melt the scrap and oxidize impurities. Slag is produced from impurities removed by the combination of the fluxes with the injected oxygen. Various alloys are added to produce different grades of steel. The molten steel is typically cast into slabs, beams or billets.

The waste products from the basic oxygen steelmaking process include slag, carbon monoxide, and oxides of iron emitted as dust. Also, when the hot iron is poured into the furnace, iron oxide fumes are released and some of the carbon in the iron is precipitated as graphite (kish). The BOF slag can be processed to recover the high metallic portions for use in sintering or blast furnaces, but its applications as saleable construction materials are more limited than the blast furnace slag.

Basic oxygen furnaces are equipped with air pollution control systems for containing, cooling, and cleaning the volumes of hot gases and sub-micron fumes that are released during the process. Water is used to quench or cool the gases and fumes to temperatures at which they can be effectively treated by the gas cleaning equipment. The resulting waste streams from the pollution control processes include air pollution control dust and water treatment plant sludge. The principal pollutants removed from the off-gas are total suspended solids and metals (primarily zinc, and some lead).

3.1.2 Steelmaking Using the Electric Arc Furnace (EAF)

In the steelmaking process that uses an electric arc furnace (EAF), the primary raw material is scrap metal, which is melted and refined using electric energy. During melting, oxidation of phosphorous, silicon, manganese, carbon, and other materials occurs and a slag containing some of these oxidation products forms on top of the molten metal. Oxygen is used to decarburize the molten steel and to provide thermal energy. Since scrap metal is used instead of molten iron, there are no cokemaking or ironmaking operations associated with steel production that uses an EAF.

The process produces metal dusts, slag, and gaseous products. Particulate matter and gases evolve together during the steelmaking process and are conveyed into a gas cleaning system. These emissions are cleaned using a wet or dry system. The particulate matter that is removed as emissions in the dry system is referred to as EAF dust, or EAF sludge if it is from a wet system. The composition of EAF dust can vary greatly depending on the scrap composition and furnace additives. The primary component is iron or iron oxides, and it may also contain flux (lime and/or fluorspar), zinc, chromium and nickel oxides (when stainless steel is being produced) and other metals associated with the scrap. Oils are burned off “charges” of oil-bearing scrap in the furnace. Minor amounts of nitrogen oxides and ozone are generated during the melting process. The furnace is extensively cooled by water which is recycled through cooling towers.

3.1.3 Forming and Finishing Operations

Whether the molten steel is produced using a BOF or an EAF, to convert it into a product, it must be solidified into a shape suitable and finished.

3.1.3.1 Forming

The traditional forming method, called ingot teeming, has been to pour the metal into ingot molds, allowing the steel to cool and solidify. This method has been largely replaced by continuous casting. The continuous casting process bypasses several steps of the conventional ingot teeming process by casting steel directly into semifinished shapes. Molten steel is poured into a reservoir from which it is released into the molds of the casting machine. The metal is cooled as it descends through the molds, and before emerging, a hardened outer shell is formed. As the semifinished shapes proceed on the runout table, the center also solidifies, allowing the cast shape to be cut into lengths.

Process contact water cools the continuously cast steel and is collected in settling basins along with oil, grease, and mill scale generated in the casting process. The scale settles out and is removed and recycled for sintering operations, if the mill has a sinter plant. Waste treatment plant sludge is also generated.

The steel is further processed to produce slabs, strips, bars, or plates through various forming operations. The most common hot forming operation is hot rolling, where heated steel is passed between two rolls revolving in opposite directions. The final shape and characteristics of a hot formed piece depend on the rolling temperature, the roll profile, and the cooling process after rolling. Wastes generated from hot rolling include waste treatment plant sludge and scale.

In subsequent cold forming, the cross-sectional area of unheated steel is progressively reduced in thickness as the steel passes through a series of rolling stands. Generally, wires, tubes, sheet and strip steel products are produced by cold rolling operations. Cold forming is used to obtain improved mechanical properties, better machinability, special size accuracy, and the production of thinner gages than hot rolling can accomplish economically. During cold rolling, the steel becomes hard and brittle. To make the steel more ductile, it is heated in an annealing furnace.

Process contact water is used as a coolant for rolling mills to keep the surface of the steel clean between roller passes. Cold rolling operations also produce a waste treatment plant sludge, primarily due to the lubricants applied during rolling. Grindings from resurfacing of the worn rolls and disposal of used rolls can be a significant contributor to the plant's wastestream.

3.1.3.2 Finishing

One of the most important aspects of a finished product is the surface quality. To prevent corrosion, a protective coating may be applied to the steel product. Prior to coating, the surface of the steel must be cleaned so the coating will adhere to the steel. Mill scale, rust, oxides, oil, grease, and soil are chemically removed from the surface of steel using solvent cleaners, pressurized water or air blasting, cleaning with abrasives, alkaline agents or acid pickling. In the pickling process, the steel surface is chemically cleaned of scale, rust, and other materials. Inorganic acids such as hydrochloric or sulfuric acid are most commonly used for pickling. Stainless steels are pickled with hydrochloric, nitric, and hydrofluoric acids.

Steel generally passes from the pickling bath through a series of rinses. Alkaline cleaners may also be used to remove mineral oils and animal fats and oils from the steel surface prior to cold rolling. Common alkaline cleaning agents include: caustic soda, soda ash, alkaline silicates, and phosphates.

Steel products are often given a coating to inhibit oxidation and extend the life of the product. Coated products can also be painted to further inhibit corrosion. Common coating processes include: galvanizing (zinc coating), tin coating, chromium coating, aluminizing, and terne coating (lead and tin). Metallic coating application processes include hot dipping, metal spraying, metal cladding (to produce bi-metal products), and electroplating. These coating processes contain many EPCRA Section 313 chemicals (mainly metals) that end up in the facility's wastestream.

3.2 Primary Aluminum Processing

Primary aluminum producers generally employ a three step process to produce aluminum ingots. First, alumina is extracted from bauxite ore using the Bayer process (Figure 3-3). In the Bayer process, finely crushed bauxite is mixed with an aqueous sodium hydroxide (caustic soda) solution to form a slurry. The slurry is then reacted at a high temperature under steam pressure in a vessel known as a digester, and creates a mixture of dissolved aluminum oxides and bauxite residues. During the reaction a majority of the impurities such as silicon, iron, titanium, and calcium oxides drop to the bottom of the digester and form a sludge. The remaining sodium aluminate solution is then flash cooled by evaporation and sent for clarification. During clarification, agents such as starch are added to help any fine impurities that remain in the slurry, such as sand, to drop out, further purifying the sodium aluminate solution. The solution is then fed into a precipitation tank to be crystallized. In the precipitation tank the sodium aluminate solution is allowed to cool with the addition of a small amount of aluminum hydroxide "seed." The seed stimulates the precipitation of solid crystals of aluminum hydroxide.

The aluminum hydroxide crystals settle to the tank bottom, and are removed. The crystals are then washed to remove any caustic soda residues, vacuum dewatered, and sent on for calcination. In the calciners (a type of rotating kiln) the aluminum hydroxide is roasted for further dewatering.

In the second step, the aluminum oxide (alumina) produced during the Bayer process is reduced to make pure molten aluminum. Alumina is dissolved in molten cryolite, and the alumina is separated into aluminum and oxygen by electric current. The electrolytic reduction process begins with the placement of the alumina into electrolytic cells, or "pots," filled with molten cyrolite. Within each pot a positive electric current is passed through the cryolite by means of a carbon anode submerged in the liquid cryolite. The oxygen atoms,

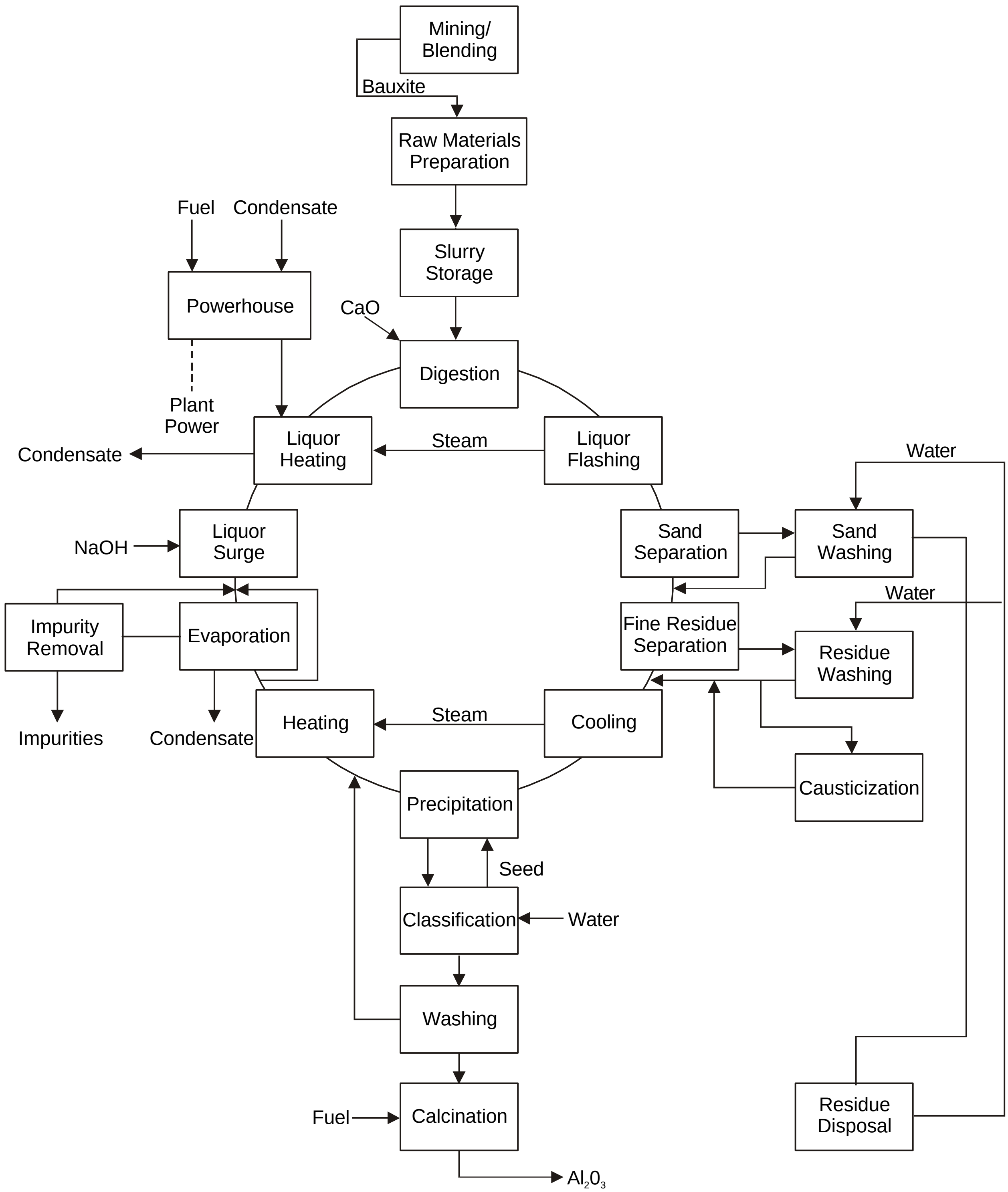


Figure 3-3. Bayer Process (Alumina Refining)

separated from aluminum oxide, carry a negative electrical charge and are attracted to the carbon anodes. The carbon and the oxygen combine immediately to form carbon dioxide and carbon monoxide. These gases bubble free of the melt. The nearly pure aluminum collects at the bottom of the pot, is siphoned off, placed into crucibles, and then transferred to melting/holding furnaces.

The third step consists of either mixing the molten aluminum with other metals to form alloys of specific characteristics, or casting the aluminum into ingots for transport to fabricating shops. Casting involves pouring molten aluminum into molds and cooling it with water. At some plants, the molten aluminum may be batch treated in furnaces to remove oxide, gaseous impurities, and active metals such as sodium and magnesium before casting. Some plants add a flux of chloride and fluoride salts and then bubble chlorine gas, usually mixed with an inert gas, through the molten mixture. Chloride reacts with the impurities to form HCl, and metal chloride emissions. A dross forms to float on the molten aluminum and is removed before casting.

Two types of anodes may be used during the reduction process: an anode paste or a pre-baked anode. Because the carbon is consumed during the refining process (about one-half pound of carbon is consumed for every pound of aluminum produced), if anode paste (Soderberg anode) is used, it needs to be continuously fed through an opening in the steel shell of the pot. The drawback to pre-baked anodes is that they require that a pre-baked anode fabricating plant be located nearby or on-site. Most aluminum reduction plants include their own facilities to manufacture anode paste and/or pre-baked anode blocks.

One waste material produced during the primary production of aluminum are fluoride compounds. Fluoride compounds are principally produced during the reduction process. One reason that pre-baked anodes are favored is that the closure of the pots during smelting facilitates the capture of fluoride emissions, though many modern smelters employ other methods to capture and recycle fluorides and other emissions.

Primary aluminum processing activities result in air emissions, process wastewaters, and other solid-phase wastes. Large amounts of particulates are generated during the calcining of hydrated aluminum oxide, but the economic value of this dust for reuse in the process is such that extensive controls are used to reduce emissions to relatively small quantities.

Small amounts of particulates are emitted from the bauxite grinding and materials handling processes. Emissions from aluminum reduction processes are primarily gaseous hydrogen fluoride and particulate fluorides, alumina, carbon monoxide, volatile organics, and sulfur dioxide from the reduction cells; and fluorides, vaporized organics and sulfur dioxide from the anode baking furnaces. A variety of control devices such as wet scrubbers are used to abate emissions from reduction cells and anode baking furnaces.

Wastewaters generated from primary aluminum processing are produced during clarification and precipitation though much of this water is fed back into the process to be reused.

Solid-phase wastes are generated at two stages in the primary aluminum process; red mud produced during bauxite refining, and spent potliners from the reduction process. Red mud normally contains significant amounts of iron, aluminum, silicon, calcium, and sodium. The types and concentrations of minerals present in the mud depends on the composition of the ore and the operating conditions in the digesters. The carbon potliners used to hold the alumina/cryolite solution during electrolytic aluminum reduction process eventually crack and need to be removed and replaced. These potliners contain cyanide complexes which form during the aluminum reduction process.

3.3 Primary Zinc Processing

The primary production of zinc begins with the reduction of zinc concentrates to metal (the zinc concentration process consists of separating the ore, which may be as little as two percent zinc, from waste rock by crushing and flotation). Zinc reduction is accomplished in one of two ways: either pyrometallurgically by distillation (retorting in a furnace) or hydrometallurgically by electrowinning. Hydrometallurgical zinc refining is discussed in this section, as this was the process seen on the site visits.

Four stages are generally used in hydrometallurgic zinc refining: calcining, leaching, purification, and electrowinning. Calcining, or roasting, is performed to eliminate sulfur and form leachable zinc oxide. Roasting is a high-temperature process that converts zinc sulfide concentrate to an impure zinc oxide. Roaster types include multiple-hearth, suspension, or fluidized-bed. The gas zinc oxide stream is directed to the baghouse (filter) area where the zinc oxide is captured in baghouse dust. All of the calcining processes generate sulfur dioxide, which is controlled and converted to sulfuric acid as a marketable process by-product.

Electrolytic processing of desulfurized calcine consists of three basic steps; leaching, purification, and electrolysis. Leaching refers to the dissolving of the captured calcine in a solution of sulfuric acid to form a zinc sulfate solution. After leaching, the solution is purified in two or more stages by adding zinc dust, which precipitates the copper and cadmium which are then filtered out.

Zinc electrowinning takes place in an electrolytic cell and involves running an electric current from a lead-silver alloy anode through the aqueous zinc compound solution. This process charges the dissolved zinc ion and deposits it onto an aluminum cathode (a plate with an opposite charge) which is immersed in the solution. Periodically, the zinc-coated cathodes are removed and rinsed, and the zinc mechanically stripped from the aluminum plates. The zinc concentrate is then melted and cast into ingots.

Electrolytic zinc smelters contain as many as several hundred cells. A portion of the electrical energy is converted into heat, which increases the temperature of the electrolyte. During electrowinning a portion of the electrolyte passes through cooling towers to decrease its temperature and to evaporate the water it collects during the process.

The sulfur dioxide generated during the primary zinc refining process is further reacted with oxygen and water to produce sulfuric acid. The wastes from the acid plant may contain sulfur, cadmium, and lead.

During the electrolytic refining of zinc, solid materials in the electrolytic solution that are not captured previously during purification may precipitate out in the electrolytic cell. When the cells undergo their periodic shutdown to recover zinc, this precipitated waste (known as anode slimes/sludges) is collected during cell cleaning.

Primary zinc processing activities generate air emissions, process wastes, and other solid-phase wastes. The material inputs and waste outputs resulting from primary zinc processing are presented by media in Table 3-1. Air emissions are generated during roasting. Sulfur dioxide emissions from the roasting processes at zinc processing facilities are generally recovered at on-site sulfuric acid plants. Much of the particulate matter emitted from primary zinc facilities is also attributable to roasters.

Table 3-1

Process Materials Inputs/Waste Outputs - Zinc

Process	Material Input	Air Emissions	Process Wastes	Other Wastes
Zinc Calcining	Zinc ore, coke	Sulfur dioxide, particulate matter containing zinc and lead		Acid plant blowdown slurry
Zinc Leaching	Zinc calcine, sulfuric acid, limestone, spent electrolyte		Wastewaters containing sulfuric acid	
Zinc Purification	Zinc-acid solution, zinc dust		Wastewaters containing sulfuric acid, iron	Copper cake, cadmium
Zinc Electrowinning	Zinc in a sulfuric acid/aqueous solution, lead-silver alloy anodes, aluminum cathodes, barium carbonate, or strontium, colloidal additives		Dilute sulfuric acid	Electrolytic cell slimes/sludges

Though the amount and composition of particulate varies with operating parameters, the particulate is likely to contain zinc and lead.

Wastewaters may be generated during the leaching, purification, and electrowinning stages of primary zinc processing when electrolyte and acid solutions become too contaminated to be reused again. This wastewater is treated before discharge.

Solid wastes are generated at various stages in primary zinc processing. Blowdown slurry generated during the operation of sulfuric acid plants is generally transferred off site. The solid copper cake generated during purification is generally sent off site to recover the copper.

3.4 Semiconductor Manufacturing

A semiconductor is a material that has an electrical conductivity between that of a conductor and an insulator; its electrical characteristics can be manipulated to behave like either depending on how it is processed. Silicon has traditionally been the substrate used to manufacture semiconductors; recently other materials such as gallium arsenide (GaAs) and indium phosphide (InP) have been used as a substrate material.

The semiconductor manufacturing process is continually evolving. The variety of distinct processing steps involved results in a range of processes that may occur at a single plant. Process designs are not uniform from plant to plant. An average semiconductor manufacturing process consists of hundreds of process steps, of which a significant percentage may be potential sources of EPCRA Section 313 chemicals. Many of the manufacturing steps are repeated several times during the production process. For these reasons, this overview will discuss general manufacturing steps and does not attempt to describe a specific type of plant.

A clean environment is essential to the manufacture of semiconductors. Thus cleaning operations precede and follow many of the manufacturing process steps. Wet processing, during which semiconductor devices are repeatedly immersed in or sprayed with solutions is commonly used to minimize the risk of contamination. Wet processes are the primary source of EPCRA Section 313 chemicals found in semiconductor manufacturing.

The primary component of a semiconductor is the semiconductor wafer, or chip. The manufacture of a semiconductor chip is essentially a six-step process (see Figure 3-4) with the following steps:

- Photolithography;
- Thin Films;
- Etching;
- Cleaning;
- Doping; and
- Chemical Mechanical Planarization.

The following sections discuss each of the processing steps identified above. It should be noted that many of the chemicals used in semiconductor manufacturing are used in more than one process, and some of the chemicals are used as a raw material as well as generated indirectly through the use of other chemicals. For example, hydrochloric acid is used in wet etching processes and is also generated in small quantities during dry etching, where chlorine plasma reacts with a hydrogen carrier to produce hydrochloric acid. Also, regardless of which process a chemical is used in, a general rule is that acid/base streams are treated in an on-site wastewater treatment plant and waste solvents are typically collected and sent off site for waste management (such as recycling or energy recovery).

3.4.1 Photolithography

Photolithography is used in semiconductor manufacturing to form surface patterns on the wafer. These patterns will in turn allow various materials to be deposited on or removed from selected, precise locations. In this process a viscous, solvent-based, light-sensitive photoresist is applied to the wafer on a spin track. On the spin track, a fixed amount of photoresist is metered onto the wafer, which is then spun at high speed on a rotating element to uniformly coat the wafer surface.

After a “soft bake” to remove most of the carrier solvent, a pattern is introduced into the resist by exposing predefined areas of the wafer with specific wavelengths of light, lasers, electron beams, or other means. A template mask, which is a glass plate containing an image of the desired circuit, may be used to introduce the pattern. Depending on the photoresist system, a developer solution is applied to dissolve some of the photoresist, yielding a stencil for further processing. Materials may be added or removed from the unmasked areas, giving a printed circuit. The number of photolithography steps required depends on the type of integrated circuit.

After the subsequent processing steps, residual photoresist is removed by using wet stripping (solvent or acid) or plasma gas stripping.

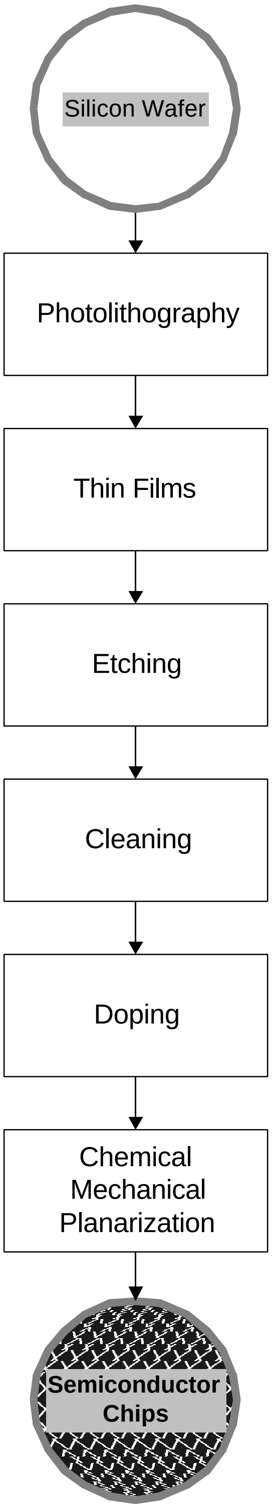


Figure 3-4. Overall Process Flow Diagram - Semiconductor Manufacturing

The most common potential sources of EPCRA Section 313 chemicals from photolithography are photoresist solvents, strippers, and developers. The primary release source is tool exhaust from the photoresist applicators, developing, and stripping stations; spent solvent, developer, and stripping solutions collected and sent either to a POTW or for off-site treatment, disposal, or energy recovery; and container residue. Typical EPCRA Section 313 chemicals include n-methyl-2-pyrrolidone, xylene (mixed isomers), certain glycol ethers, ammonia, and methyl ethyl ketone. Ammonium compounds are commonly used as developers.

Release and other waste management activity types include fugitive and point source emissions to the air from wet chemical and solvent stations and control equipment exhaust, and off-site transfers to POTWs, treatment facilities, and waste management facilities. Vapors from organic solvents found in the photoresist and photoresist strippers are typically sent to an on-site treatment unit, usually some type of concentrator (such as a carbon absorber) followed by thermal destruction.

3.4.2 Thin Films

In thin film deposition, layers of single crystal silicon, polysilicon, silicon nitride, silicon dioxide, and other materials are deposited on the wafer to provide desirable properties on portions of the device or to serve as masks. Deposition of these films is frequently performed in a chemical vapor deposition (CVD) reactor or a high-temperature tube furnace using silicon-containing gases as reactants. The deposition rate can be further enhanced by striking a plasma to overcome kinetic barriers. Selected impurity compounds or dopants may be used in the deposition process to alter the electrical characteristics of the deposited film or layer. Sometimes chlorine gas, hydrochloric acid (acid aerosols), or 1,1,1-trichloroethane is used during oxidation to modify the oxide characteristics.

Typical EPCRA Section 313 chemicals used in these deposition processes are chlorine, anhydrous ammonia, hydrochloric acid (acid aerosols) 1,1,1-trichloroethane, and 1,2-dichloroethylene.

To interconnect electrical devices on an integrated circuit and to provide for external connections, metallic layers are deposited onto the wafer by evaporation, sputtering, or

CVD. Evaporation consists of vaporizing a metal under a vacuum at a very high temperature. Sputtering processes (also called physical vapor deposition or PVD) involve bombarding metallic targets with a plasma gas, which displaces ions from the target and deposits them on the wafer. CVD of metal is similar to the other deposition processes described above except that the reactive gas is a metal-containing vapor. Devices may have a single layer or multiple layers of metal.

Typical EPCRA Section 313 chemicals used in metallization processes are ammonia and compounds of chromium, copper, and nickel.

The most common potential source of EPCRA Section 313 chemicals from application of thin films is ammonia gas used as a nitrogen source in silicon nitride deposition, organics used as chlorine sources and as a cleaner for deposition furnaces, and metals deposited to interconnect electrical devices. The primary point of release is the thin film deposition tool (furnace or oxidation chamber). Exhaust from these tools is typically routed to a scrubber which vents to the atmosphere and also result in wastewater generation. It should be noted that metals are not typically used in amounts that would exceed the reporting threshold. Release and other waste management activity types from thin film deposition processes include point source air, on-site treatment, and off-site disposal.

3.4.3 Etching

Etching is used to chemically remove specific unwanted areas of silicon substrate or deposited film so that an underlying material may be exposed or another material may be deposited in the etched material's place. Etch processes usually occur after a photoresist pattern has been applied, so that the etching is accomplished in specific areas.

Etching may be performed using either solutions of acids, bases, or oxidizers (wet etch), or by using various gases (usually halogenated) excited by striking a plasma (dry etch). In either case, the fluoride ion or radical is almost always introduced if the substrate or film to be etched contains silicon.

Typical examples of chemicals used in etch processes include 1,1-dichloro-l-fluoroethane, chlorine, ethylene glycol, hydrochloric acid (acid aerosols), hydrogen fluoride, nitric acid, phosphoric acid, and sulfuric acid (acid aerosols).

The most common potential source of EPCRA Section 313 chemicals from etching is the etchant material itself, usually inorganic acids used in wet etching processes, and certain halogenated organics used in dry etching processes. Acid gasses from the etching tools are usually vented through a scrubber, which in turn sends spent scrubber water to an on-site treatment plant for neutralization prior to discharge to a receiving stream or POTW. Release and other waste management activity types include stack air, fugitive air, container residue, and discharge to a POTW.

3.4.4 Cleaning

Cleaning of wafers is required to prepare them for each chemical and physical process to ensure that contaminants on the wafer surfaces do not affect the final integrated circuit's electrical performance. Before, and sometimes after, wafers are subjected to any specialized manufacturing processes, they are typically immersed in or sprayed with various aqueous and/or organic solutions. In some cases they are mechanically scrubbed in some manner to remove films, residues, bacteria, or other particles. Fog chambers may also be used for wafer cleaning.

Typical sources of EPCRA Section 313 chemicals from cleaning operations would be cleaning station exhaust vents, waste solvents, and container residue (from "empty" containers of the cleaning solution). Release and other waste management activity types from this process include stack and fugitive air emissions; off-site transfer of the spent cleaning solutions; wastewater discharges (either direct or to a POTW); and transfers of "empty" shipping containers to off-site locations.

3.4.5 Doping

Doping is a process in which specific atoms of impurities are introduced into the silicon substrate to alter the electrical properties of the substrate by acting as charge carriers. Doping is typically accomplished through ion implantation or diffusion processes.

Ion implantation is the most common method used to introduce impurity atoms into the substrate. The dopant atoms are first ionized with a medium-to-high-current filament, then accelerated toward the wafer surface with large magnetic and electrical fields. Because of the high kinetic energy of the ions during bombardment, damage to the substrate's crystalline structure occurs. To restore the substrate's structure to a satisfactory level, slow heating or "annealing" of the amorphous material in various gaseous atmospheres is subsequently performed.

Diffusion is a high-temperature process also used to introduce a controlled amount of a dopant gas into the silicon substrate. The process occurs in a specially designed tube furnace where dopants may be introduced in one of two primary ways: dopant gases may be introduced into the furnace that will diffuse into the exposed areas of the substrate (gaseous diffusion), or dopant atoms may diffuse into the substrate from a previously deposited dopant oxide layer in the areas where the two are in contact (nongaseous diffusion).

Typical EPCRA Section 313 chemicals used in doping processes are boron trifluoride and compounds of antimony, barium, and nickel.

The most common potential source of EPCRA Section 313 chemicals from doping are the dopants themselves, as well as certain organic compounds that may be used as furnace cleaning gases or chlorine sources. The physical release points are tool and control device exhaust vents, spent cleaning solutions, and solid or hazardous waste generated as part of the process.

Organic chemicals may be emitted from furnace exhaust and may also be collected and sent off site for energy recovery or disposal.

3.4.6 Chemical Mechanical Planarization

Chemical Mechanical Planarization (CMP) is used in semiconductor manufacturing to remove the top layer of material from the wafer in a controlled manner, leaving a smooth and flat surface for further processing. This technology is applied in two ways. The first is to selectively remove the top part of a nonconducting layer or film to reduce the topography on the wafer (also called planarization). The second type of CMP is removal of excess material from the surface of conducting layers (metals).

The only notable source of EPCRA Section 313 chemicals from CMP is the planarization process which typically contains ferric nitrate ($Fe(NO_3)_3$), a nitrate compound. Spent slurries containing nitrates are typically sent off site to a POTW.

3.5 Printed Wiring Board Manufacturing

Printed wiring boards (PWBs) are the physical structures on which electronic components such as semiconductors and capacitors are mounted. PWBs are subdivided into single-sided, double-sided, multilayer, and flexible boards. Multilayer boards are manufactured similarly to single and double-sided boards, except that conducting circuits are etched on both the external and internal layers. Multilayer boards allow for increased complexity and density. PWBs are produced using three methods: additive, subtractive, or semi-additive technology. The subtractive process accounts for a significant majority, perhaps 80%, of PWB manufacturing.

The conventional subtractive manufacturing process begins with a board, consisting of epoxy resin and fiberglass, onto which patterns are imaged. In most operations, conducting material, usually copper, is bonded onto the substrate surface to form copper-clad laminate. After drilling holes through the laminate and making those holes conductive, unwanted copper is etched off, leaving copper patterns. The patterns on the board form the electric circuits that conduct electricity. Multilayer boards typically use metals such as platinum, palladium, and copper to form electric circuits. Specialized PWBs may use nickel, silver, or gold.

Additive technology is used less often than subtractive technology because it is a more difficult and costly production process. This capital-intensive technology is used primarily for small interconnection components used in multi-chip devices. The production process begins with a base plate upon which a dielectric material is deposited. An interconnecting layer of copper is plated onto the dielectric layer which connects the layers of dielectric material and copper. Copper posts are plated-up and another layer of dielectric material is deposited exposing the posts. The next interconnect layer is plated and makes contact with the posts. Layers of dielectric material, copper, and copper posts are added to complete the interconnect. A lithographic process, similar to the one used in semiconductor manufacturing, diminishes the spaces and widths of the PWB.

This section provides a simplified discussion of the steps commonly performed during conventional subtractive manufacturing. These steps are outlined below:

- Board preparation;
- Application of conductive coatings (plating);
- Soldering;
- Fabrication; and
- Assembly.

3.5.1 Board Preparation

Board preparation begins with a lamination process. Two-side etched copper dielectric boards (consisting usually of fiberglass and epoxy resin) are separated by an insulating layer and laminated or bonded together, usually by heat and pressure. Photographic tools are used to transfer the circuit pattern to the PWB, and computer control programs are used to control the drilling, routing, and testing equipment. Preparing the copper-clad board involves drilling holes to establish an electrical path between the layers and to mount components. The boards are then mechanically cleaned to remove drilling wastes (i.e., fine particulate contaminants, such as copper). Vapor degreasing, abrasive cleaning, chemical cleaning with alkaline solutions, acid dips, and water rinses are techniques used to clean the boards and prepare them for the next process, electroless plating. Table 3-2 shows materials used during lamination, drilling, and cleaning processes.

Table 3-2

Chemicals Used in Lamination, Drilling, and Cleaning

Lamination	Drilling	Cleaning
Epoxies	Sulfuric acid Potassium permanganate Ammonium bifluoride Oxygen Fluorocarbon gas	Acetone 1,1,1-Trichloroethane Silican (and other abrasives) Sulfuric acid Aqueous ammonia Hydrochloric acid

Source: Based on EPA DfE 1993: *Industry Profile and Description of Chemical Use for the Printed Wiring Board Industry*: Preliminary Draft.

Wastes generated include: airborne particulates, acid fumes, and organic vapors from cleaning, surface preparation, and drilling; spent acid and alkaline solutions; spent developing solutions, spent etchings, and waste rinsewaters in the wastewater; and scrap board materials and sludges from wastewater treatment. Drilling and routing dust (copper, aluminum, and gold) are collected and recycled.

3.5.2 Electroless Plating

The first process in this step is to prepare the surfaces of the drilled holes. The holes are prepared by an etchback process to remove smeared epoxy resin and other contaminants using one of the following: sulfuric or hydrochloric acid; potassium permanganate; or carbon tetrafluoride, oxygen and nitrogen. The holes are then coated with a material such as copper or graphite carbon, by a chemical process called electroless plating.

Electroless plating coats a uniform conducting layer of copper or other material on the entire surface including the barrels of the holes of the prepared board without outside power sources. This coating of copper is not thick enough to carry an electrical current, but provides a base upon which additional copper can be deposited electrolytically. Chemical deposition is the technique used to coat the board. After the electroless plating, the boards are dried to prevent the board from oxidation (e.g., rusting). The board may also be cleaned to prepare for a following electroplating processing. Table 3-3 shows a list of material used. Wastes generated include:

spent electroless copper baths; spent catalyst solutions; spent acid solutions; waste rinsewaters; and sludges from wastewater treatment.

Table 3-3

Materials Used in Copper and Tin-Lead Electro- and Electroless Plating Processes

Type of Plating	Electroplating Chemicals	Electroless Chemicals
Copper	Copper pyrosphate Orthophosphate Pyrophosphate Nitrates Ammonia Acid copper Copper sulfate Sulfuric acid	Hydrochloric acid Palladium chloride Stannous chloride Metallic tin pellets Sodium hydroxide Copper sulfate Formaldehyde
Tin-Lead	Tin-Lead Fluoroboric acid Boric Acid Peptone	Tin chloride Sodium hypophosphite Sodium citrate

Source: Based on EPA DfE 1993: Industry Profile and Description of Chemical Use for the Printed Wiring Board Industry: Preliminary Draft.

3.5.3 Imaging

During imaging, circuit patterns are transferred onto the boards through photolithography or a stencil printing process. Photoresist (i.e., a light sensitive chemical) is applied to the board in areas where the circuit pattern will not be set. The board is exposed to a radiation source and developed to remove the unwanted areas of the resist layer. Stencil printing uses a printing process, such as silk screening, to apply a protective film that forms the circuit pattern.

After photolithography, the boards are subjected to a light etching process, typically using etchants containing ammonia, to remove rust inhibitor or other metals (usually copper). After the stencil printing process, the protective film is dried, and the exposed copper is etched away. Sulfuric acid and hydrogen peroxide are common etchants used during imaging. After plating or etching, the photoresist is removed with a photoresist stripper.

Tables 3-4 and 3-5 present a list of materials used during photolithography and etching process. Wastes generated include organic vapors and acid fumes, spent developing solutions, spent resist material, spent etchant, spent acid solutions, and sludges from wastewater treatment.

Table 3-4

Chemicals Used in Photolithography for Printed Wiring Boards

Resists	Photopolymer Developers	Photopolymer Strippers
Mylar Vinyl Photoresists	Isopropyl alcohol Potassium bicarbonate Sodium bicarbonate 1,1,1-Trichloroethane Amines Glycol ethers	Sodium hydroxide Potassium hydroxide Methylene chloride

Source: Based on EPA DfE 1993: Industry Profile and Description of Chemical Use for the Printed Wiring Board Industry: Preliminary Draft.

Table 3-5

Materials Used During Etching

Ammonia Ammonium chloride Ammonium persulfate Ammonium sulfate Boric acid Carbon tetrafluoride Chlorine	Cupric chloride Hydrochloric acid Hydrofluoric acid Hydrogen peroxide Lead	Nickel Nickel chloride Nickel sulfamate Nitrate Nitric acid Nitrogen Orthophosphate Oxygen Peptone	Permanganates Sodium citrate Sodium hydroxide Stannous chloride Sulfuric acid Tin

Source: Based on EPA DfE 1993: Industry Profile and Description of Chemical Use for the Printed Wiring Board Industry: Preliminary Draft.

3.5.4 Electroplating

Electroplating is a process in which a metal is deposited on a substrate through electrochemical reactions. Electroplating is required to build up the thickness and strength of the conducting layers to provide reliable electrical conductivity between inner layers or from one side of the PWB to the other. Electroplating can also protect against corrosion, wear, or erosion.

This process involves immersing the article to be coated/plated into a bath containing acids, bases, or salts.

The electroplating process for PWBs usually begins with the copper laminate which is coated with a plating resist (photolithography), by stenciling, leaving the area exposed to form the circuit pattern. The resist prevents the conductive material from adhering to other areas of the board and forms the circuit pattern.

The PWB plating process typically uses copper and tin-lead as plating materials, although silver, nickel, or gold can be used. Copper in a plating bath solution is deposited to a sufficient thickness, and a solvent or aqueous solution is applied to remove the plating resist. The copper coating forms interconnections between the layers and provides electrical contact for electronic parts mounted or assembled on the PWB surface. PWB manufacturers then typically electroplate a tin or tin-lead solder on the board to protect the circuit pattern during the following etching or stropping processes. An acid etch solution (ammonia, peroxide solutions, sodium persulfate, cupric chloride, or ferric chloride) removes the exposed copper foil, leaving the thicker copper plating to form the circuit pattern. Ammonia and cupric chloride are the primary etchants used by PWB manufacturers. Fluoroboric acid is used in the tin-lead plating process to keep the metals dissolved in the solution and to ensure a consistent deposition of the tin-lead alloy onto the circuit board.

After the plating bath, the board is rinsed with water, scrubbed, and then dried to remove the copper, spray etch solutions, and other materials. Rinsing ends the chemical reactions during plating and prevents contamination or dragout from being released in the next bath or rinse water (dragout is the plating solution that sticks to parts after taken out of the plating bath). Dragout can occur in any bath step, not just in one plating bath. The tin-lead layer is generally removed and the panel is electrically tested for discontinuities in the electrical pathway and shorts. Table 3-3 presents a list of materials used during the electroplating process.

Wastes generated during plating include: spent acid solutions, waste rinsewaters, spent developing solutions, spent etchant, and spent plating baths in the wastewater; organic vapors from spent developing solution and spent resist removal solution; and acid and ammonia fumes.

3.5.5 Soldering Coating

Solder coating is used to add solder to PWB copper components before component assembly. All methods of solder coating involve dipping the panel into molten solder. The solder, an alloy consisting of 60 percent tin and 40 percent lead, coats the pads and holes not covered by solder mask. The excess solder is removed with a blast of hot oil or hot air. However, the hot oil or hot air does not remove the solder that has formed a chemical (intermetallic) bond with the copper. The most common process is hot-air leveling.

3.5.6 Electrical and Mechanical Testing

A cross section is cut from a sample panel from each lot using a grinding process called routing, and the plated holes are examined with a photomicrograph. Individual circuit boards are cut out of panels that pass quality control. Routing generates dust which may contain copper, lead, or other metals plated to the panel, but the dust is recycled. Electrical tests, dimensional and visual inspections, and quality audits are performed to ensure compliance with customer requirements. Finally, the finished PWBs are packaged, labeled, and shipped to the customer.

3.5.7 Printed Wiring Board Assembly and Soldering

After the PWBs are manufactured, the electrical components are attached during assembly. Adhesives are applied to the boards, and then the components are attached and soldered to the boards. Components are attached to the PWB by a process called soldering. There are several different kinds of soldering processes, including wave, dip, and drag.   A type of chemical known as "flux" is used before soldering to facilitate the production of the solder connection. Not only does flux clean the surface and remove oxidized material, it prevents oxidation from occurring during the solder process. After the solder has been applied, flux residue may be removed from the board, and the board may be cleaned and dried.

The wastes generated during assembly include: solder dross, post-solder scrap boards, filters, gloves, rags, and spent gaseous or semi-gaseous solvents from cleaning processes. The wastes that may be generated during soldering, flux application, and cleaning include: organic vapors, copper, lead, spent solvents, and spent deionized water into the wastewater; solder dross; and wastewater treatment sludge. Solder dross is primarily oxidized solder skin that forms on any molten solder exposed to oxygen and can be recycled off site.

3.6 Motor Vehicle Equipment Manufacturing

Motor vehicle parts and accessories include both finished and semi-finished components. Approximately 8,000 to 10,000 different parts are ultimately assembled into approximately 100 major motor vehicle components, including suspension systems, transmissions, and radiators. These parts are eventually transported to an automotive manufacturing plant for assembly.

The manufacturing process used to produce the thousands of discrete parts and accessories vary depending on the end product and materials used. Different processes are employed for the production of metal components versus the production of plastic components. Most processes, however, typically include casting, forging, molding, extrusion, stamping, and welding.

3.6.1 Foundry Operations

Foundries, whether they are integrated with automotive assembly facilities or independent shops, cast metal products which play a key role in the production of motor vehicles and motor vehicle equipment. Iron and steel are currently the major metal components of an automobile with increasing use of aluminum and other metals. The following discussion focuses on iron foundries and associated production processes.

The main steps in producing cast iron motor vehicle products are as follows (see Figure 3-5):

- Pattern design and production;
- Sand formulation;
- Mold and core production;
- Metal heating and alloying;
- Metal molding;
- Mold shakeout;
- Production finishing and heat treating; and
- Inspection.

The process begins with the mixing of moist silica sand with clay and water to produce the "green sand," which forms the basis of the mold. Other additives, including organics such as seacoal or oat hulls, may be added to the green sand to help prevent casting defects. The core is then created using molded sand and often includes binders, such as resins, phenol, and/or formaldehyde. The core is the internal section of a casting used to produce the open areas needed inside such items as an engine or a drive train. After the core has been molded, it is baked to ensure its shape, and then combined with the rest of the casting mold in preparation for casting. At the same time the core is being created, iron is being melted. The iron charge, whether it be scrap or new iron, is combined with coal (as a fuel) and other additives such as calcium carbide and magnesium, and fed into a furnace, which removes sulfur (usually an electric arc, an electric induction, or a cupola furnace).

Calcium carbide may be added for certain kinds of iron casting, and magnesium is added to produce a more ductile iron. Once the iron reaches the appropriate temperature, it is poured into the prepared mold. The mold then proceeds through the cooling tunnel and is placed on a grid to undergo a process called "shakeout." During shakeout the grid vibrates, shaking loose the mold and core sand from the casting. The mold and core are then separated from the product which is ready for finishing.

The finishing process is made up of many different steps depending upon the final product. The surface may be smoothed using an oxygen torch to remove any metal snags or chips, it may be blast-cleaned to remove any remaining sand, or it may be pickled using acids to achieve the correct surface. If necessary, the item may be welded to ensure the tightness of any

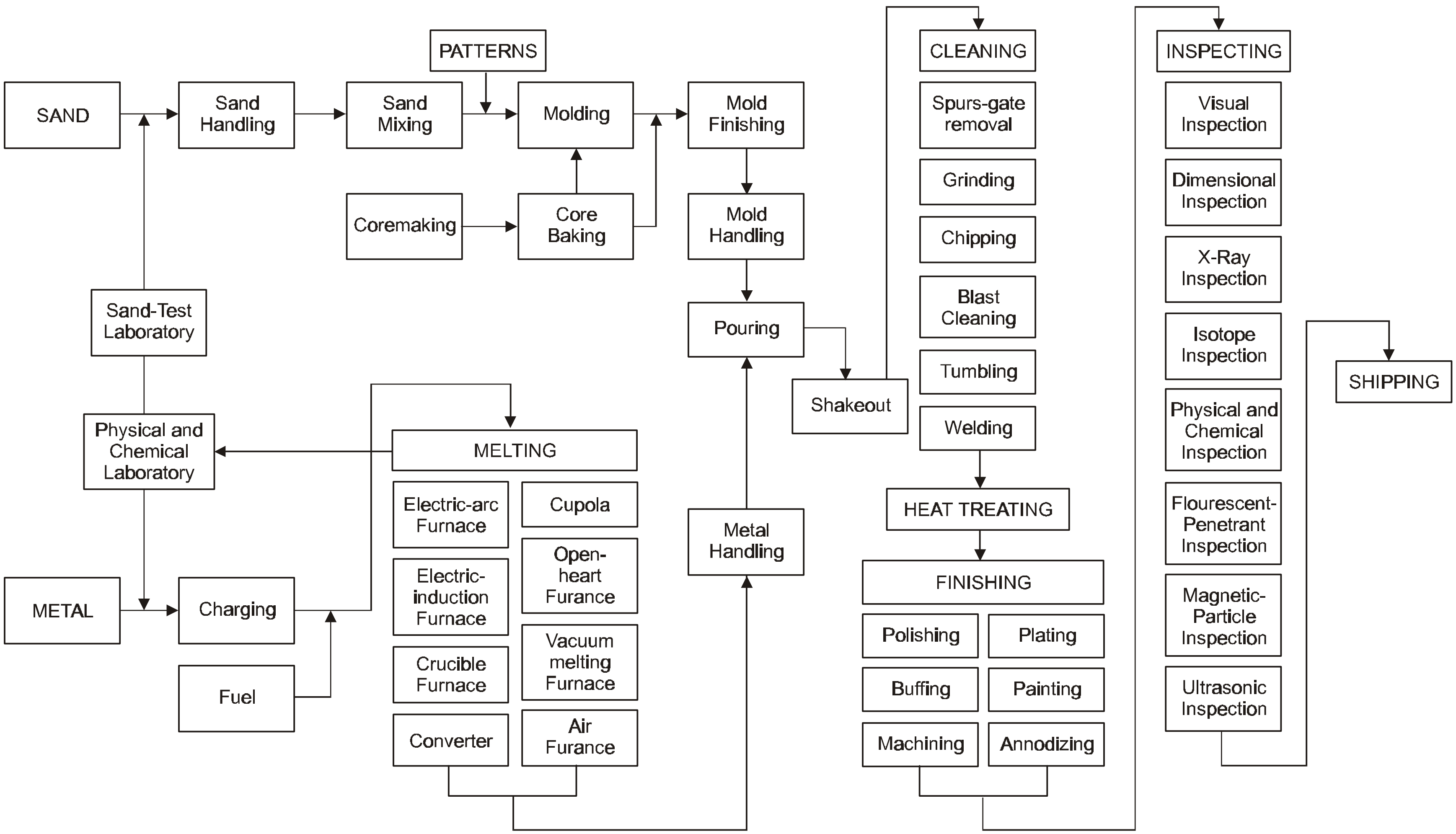


Figure 3-5. General Foundry Flow Diagram

seams or seals. After finishing, the item undergoes a final heat treatment to ensure it has the proper metallurgical properties. The item is then ready for inspection. Inspection may take place in any number of ways, be it visually, by x- or gamma ray, ultrasonic, or magnetic particle. Once an item passes inspection, it is ready to be shipped to the assembly area.

Iron foundries create a number of air emissions, process wastewaters, and solid wastes. Gas and particulate emissions occur throughout the casting process. Dust created during sand preparation, molding, and shakeout is prevalent. Gases containing lead and cadmium and other particulate matter and sulfur dioxide are also created during foundry operation, especially during the melting of the iron.

The wastewaters generated during foundry operations are primarily from slag quenching operations (water is sprayed on the slag to both cool it as well as pelletize it) and by the wet scrubbers employed as air pollution control devices connected to furnaces and sand and shakeout operations. Due to the presence of cadmium and lead in iron, these metals may both be present in wastewaters.

3.6.2 Metal Fabricating

Another major process in the manufacturing of automotive parts is metal fabrication. Metal fabrication involves the shaping of metal components. Many automotive parts, including fenders, hubcaps, and body parts are manufactured in metal fabricating shops.   Typical large-scale production of these items starts with molten metal (ferrous or nonferrous) containing the correct metallurgical properties. Once the metal has been produced, it is cast into a shape that can enter the rolling process. Shearing and forming operations are then performed to cut materials into a desired shape and size and bend or form materials into specified shapes.

Shearing (or cutting) operations include punching, piercing, blanking, cutoff, parting, shearing, and trimming. Basically, these are operations that produce holes or openings, or that produce blanks or parts. Forming operations shape parts by forcing them into a specified configuration, and include bending, forming, extruding, drawing, rolling, spinning, coining, and forging.

Once shearing and forming activities are complete, the material is machined. This entails shaping or forming a workpiece by removing material from pieces of raw stock with machine tools. The principal processes involved in machining are hole-making, milling, turning, shaping/planing, broaching, sawing, and grinding.

Each of the metal shaping processes can result in wastes containing EPCRA Section 313 chemicals. In general, there are two categories of waste generated in metal shaping operations: scrap metal and metalworking fluids/oils.

Scrap metal may consist of metal removed from the original piece (e.g., steel or aluminum). Quite often, scrap is reintroduced into the process as feedstock.

In general, metalworking fluids can be petroleum-based, oil-water emulsions, or synthetic emulsions that are applied to either the tool or the metal being tooled to facilitate the shaping operation. Metalworking fluids typically become contaminated and spent with extended use and reuse. When disposed, these fluids may contain contaminants, including chlorine, sulfur an phosphorous compounds, phenols, cresols, and alkalines, as well as metals. Air emissions may result through volatilization during storage, fugitive losses during use, and direct ventilation of fumes.

3.6.3 Metal Finishing/Electroplating

The final process in manufacturing motor vehicle parts is metal finishing and electroplating. Numerous methods are used to finish metal products. However, prior to applying the finishing application, the surface must be prepared. One of the most important aspects of a finished product is the surface cleanliness and quality. Without a properly cleaned surface, even the most expensive coatings will fail to adhere or prevent corrosion. The steel motor vehicle parts are generally cleaned with nitric, hydrochloric, and hydrofluoric acid, as well as alkaline cleaning agents.

Metal finishing and electroplating activities are performed on a number of metals and serve a variety of purposes; the primary purpose being protection against corrosion. This is particularly important to the automotive industry because of the harsh weather and road conditions to which automobiles may be subject. Metal finishing and electroplating can also be performed for decorative purposes. These plating processes involve immersing the article to be coated/plated into a bath consisting of acids, bases, salts, etc.

The metals used in electroplating operations (both common and precious metal plating) include cadmium, lead, chromium, copper, nickel, zinc, gold, and silver. Cyanides are also used extensively in electroplating solutions and in some stripping and cleaning solutions.

Electroless plating is the chemical deposition of a metal coating onto a metal object, by immersion of the object in an appropriate plating solution. In electroless nickel plating, the source of nickel is a salt, and a reducer is used to reduce the nickel to its base state. A complexing agent is used to hold the metal ion in the solution. Immersion plating produces a metal deposit by chemical displacement. Immersion plating baths are usually formulations of metal salts, alkalies, and complexing agents (typically cyanide or ammonia).

Etching is the process used to produce specific design configurations or surface appearances on parts by controlled dissolution with chemical reagents or etchants. Etching solutions are commonly made up of strong acids or bases with spent etchants containing high concentrations of spent metal. The solutions include ferric chloride, nitric acid, ammonium persulfate, chromic acid, cupric chloride, and hydrochloric acid.

Anodizing uses the piece to be coated, generally with an aluminum surface, as an anode in an electrolytic cell. Anodizing provides aluminum parts with a hard abrasion- and corrosion-resistant film. This coating is porous, allowing it to be dyed or to absorb lubricants. This method is used both in decorative applications, including automotive trim and bumper systems, and in engineering applications such as aircraft landing gear struts. Anodizing is usually performed using either sulfuric or chromic acid often followed by a hot water bath, though nickel acetate or sodium potassium dichromate seal may also be used.

Surface preparation operations generate wastes contaminated with solvents and/or metals depending on the type of cleaning operation. Concentrated solvent-bearing wastes and releases may arise from degreasing operations. Degreasing operations may result in solvent-bearing wastewaters, air emissions, and materials in solid form.

Surface finishing and related washing operations account for a large volume of wastes associated with automotive metal finishing. Metal plating and related waste account for the largest volumes of metal (e.g., cadmium, chromium, copper, lead, mercury, and nickel) and cyanide-bearing wastes.

Electroplating operations can result in solid and liquid wastestreams that contain EPCRA Section 313 chemicals. Liquid wastes result from workpiece rinses and process cleanup waters. Most surface finishing (and many surface preparation) operations result in liquid wastestreams. Centralized wastewater treatment systems are common, and can result in solid-phase wastewater treatment sludges. In addition to these wastes, spent process solutions and quench baths are discarded periodically when the concentrations of contaminants inhibit proper function of the solution or bath. When discarded, process baths usually consist of solid- and liquid-phase wastes that may contain high concentrations of acids, bases, and cyanide wastes.

3.7 Motor Vehicle Painting/Finishing

Automotive finishing is a multi-step process subdivided into four categories: 1) anti-corrosion operations, consisting of cleaning applications, a phosphate bath, and a chromic acid bath; 2) priming operations, consisting of an electrodeposition primer bath, an anti-chip application, and a primer-surfacer application; 3) joint sealant application; and 4) finishing operations, consisting of a color coat application, a clear coat application, and any painting necessary for two-tone color or touch-up applications. The stages of the automotive finishing process are illustrated in Figure 3-6

After the automobile body has been assembled, anti-corrosion operations prepare the body for the painting/finishing process. Initially, the body is sprayed with or immersed in a cleaning agent, typically consisting of detergents, to remove residual oils and dirt. The body is then dipped into a phosphate bath, typically zinc phosphate, to prevent corrosion. The phosphate process also improves the adhesion of the primer to the metal. The body is then rinsed with chromic acid, further enhancing the anti-corrosion properties of the zinc phosphate coating. The anti-corrosion operations conclude with another series of rinsing steps.

Priming operations further prepare the body for finishing by applying various layers of coatings designed to protect the metal surface from corrosion and assure good adhesion of subsequent coatings. Prior to the application of these primer coats, however, plastic parts to be painted and finished with the body are installed.

A primer coating is applied to the body using an electrodeposition method, creating a strong bond between the coating and the body to provide a more durable coating. In electrodeposition, a negatively-charged auto body is immersed in a positively-charged bath of primer. The coating particles, insoluble in the liquid and positively-charged, migrate toward the body and are, in effect, “plated” onto the body surface.

Although the primer bath is mostly water-based with only small amounts of organic solvent (less than five percent to ten percent), fugitive emissions consisting of volatile organic compounds (VOCs) can occur. However, the amount of these emissions is quite small. In addition to solvents and pigments, the electrodeposition bath contains small amounts of lead.

Prior to baking, excess primer is removed through several rinsing stages. The rinsing operations use various systems to recover excess electrodeposited primer. Once the body is thoroughly rinsed, it is baked. VOC emissions resulting from the baking stage are generally incinerated.

Next, the body is further water-proofed by sealing spot-welded joints of the body. Water-proofing is accomplished through the application of a paste or putty-like substance. This sealant usually consists of polyvinyl chloride and small amounts of solvents. The body is again baked to ensure that the sealant adheres thoroughly to the spot-welded areas.

After water-proofing, the automobile body proceeds to the anti-chip booth. Here, a substance usually consisting of a urethane or an epoxy ester resin, in conjunction with solvents, is applied locally to certain areas along the base of the body, such as the rocker panel or the front of the car. This anti-chip substance protects the lower portions of the automobile body from small objects, such as rocks, which can fly up and damage automotive finishes.

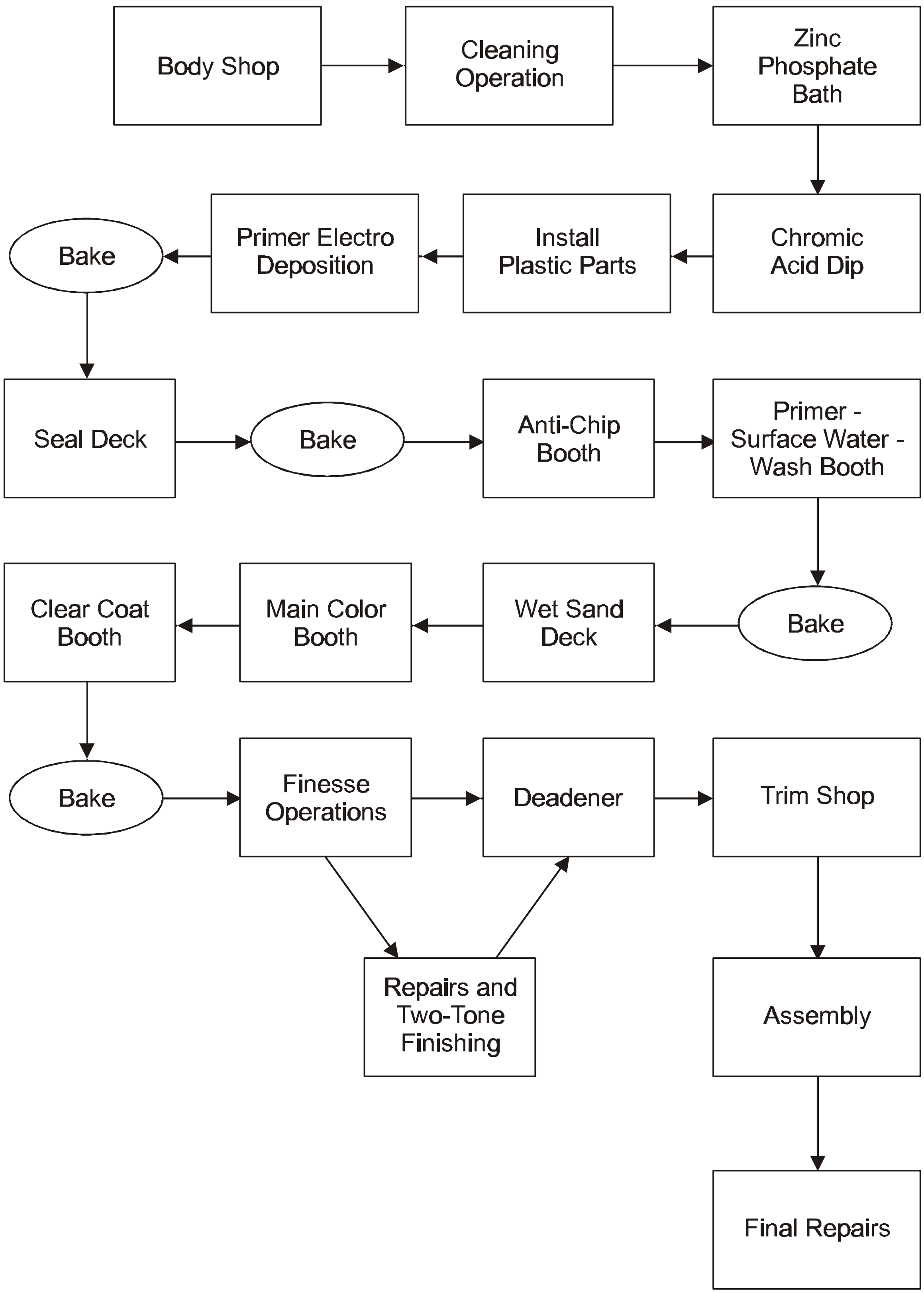


Figure 3-6. Car Painting Process

The primer-surfacer coating, unlike the initial electrodeposition primer coating, is applied by spray application in a water-wash spray booth. The primer-surfacer consists primarily of pigments, polyester or epoxy ester resins, and solvents. Due to the composition of this coating, the primer-surfacer creates a durable finish which can be sanded. The pigments used in this finish provide additional color layers in case the primary color coating is damaged. A continuous stream of air, usually from ceiling to floor, is used to transport airborne particulates and solvents from the primer-surfacer overspray. The air passes through a water curtain which captures a portion of the airborne solvents for reuse or treatment at a waste water facility. Efforts have been made at certain facilities to recycle this air to reduce VOC emissions.

After the primer-surfacer coating is baked, the body is then sanded, if necessary, to remove any dirt or coating flaws. This is accomplished using a dry sanding technique. Particulate matter is generated during this process.

The next step of the finishing process is the application of the primary color coating. This is accomplished in a manner similar to the application of primer-surfacer. One difference between these two steps is the amount of pigments and solvents used in the application process. VOC emissions from primary color coating operations can be double that released from primer-surfacer operations. In addition to the pigments and solvents, aluminum or mica flakes can be added to the primary color coating to create a finish with unique reflective qualities. Instead of baking, the primary color coat is allowed to "flash off," in other words, the solvent evaporates without the application of heat. This evaporation contributes to significant air emissions.

After the primary color coating is allowed to air-dry briefly, the final coating, a clear coat, is applied. The clear coat adds luster and durability to the automotive finish. This coating generally consists of a modified acrylic or a urethane and is baked on. Following the baking of the clear coat, the body is inspected for imperfections in the finish. Operators finesse minor flaws through light sanding and polishing and without any repainting.

Once the clear coat is baked, a coating known as deadener is applied to certain areas of the automobile underbody. Deadener, generally a solvent-based resin of tar-like consistency, is applied to areas such as the inside of wheel wells to reduce noise. In addition, nti-corrosion wax is applied to other areas, such as the inside of doors, to further seal the automobile body and prevent moisture damage. This wax contains aluminum flake pigment and is applied using a spray wand.

The finished vehicle is then inspected to ensure that no damage has occurred as a result of the final assembly stages. If there is major damage, the entire body part is replaced. However, if the damage is minor, such as a scratch, paint is taken to the end of the line and applied using a hand-operated spray gun.

Many of the wastes generated during automotive production are the result of painting and finishing operations. These operations result in air emissions as well as the generation of solid and liquid wastes.

Air emissions, primarily VOCs, result from the painting and finishing application processes (paint storage, mixing, applications, and drying) as well as cleaning operations. These emissions are composed mainly of organic solvents containing EPCRA Section 313 chemicals which are used as carriers for the paint. Solvents are also used during cleanup processes to clean spray equipment between color changes, and to clean portions of the spray booth. Solvents are often composed of a mixture of dimethyl-benzene, acetone, 4-methyl-2-pentanone, butyl ester acetic acid, light aromatic solvent naphtha, ethyl benzene, hydrotreated heavy naphtha, 2-butanone, toluene, and 1-butanol.

Various solid and liquid wastes may be generated throughout painting operations. These wastes generally contain the solvents with EPCRA Section 313 chemicals listed above. Solid and liquid wastes may also contain metals from paint pigments and organic solvents.

4.0 THRESHOLD DETERMINATIONS

This section reviews how accurately facilities determined whether EPCRA Section 313 chemicals exceeded TRI reporting thresholds and the extent to which incorrect threshold determinations ultimately affect the quality of the TRI database. Threshold determinations are a critical element in determining whether facilities must report the release and other waste management quantities of EPCRA Section 313 chemicals. More specifically, errors in threshold determinations can cause facilities to fail to submit Form Rs for chemicals that meet the reporting criteria, which may cause the TRI database to understate the magnitude of release and other waste management quantities. This section considers the following topics when evaluating how threshold determinations affect the quality of TRI data:

- Approaches commonly used to calculate thresholds (Section 4.1)
- Frequency of incorrect threshold determinations (Section 4.2)
- Reasons for making incorrect threshold determinations (Section 4.3)

The section concludes by reviewing key findings and offering several recommendations for improving future reporting practices.

This section does not differentiate facilities that submitted Form R reports from those facilities that submitted Form A reports (i.e., alternate certification statements). Section 7 of this report provides specific details on the frequency with which facilities choose to submit Form As.

4.1 Approaches Used for Determining Thresholds

This subsection summarizes the approaches that the surveyed facilities used to calculate thresholds and correlates selected approaches with the accuracy of threshold determinations. For every EPCRA Section 313 report reviewed during the site visits, surveyors documented the approach used to determine thresholds using the following categories:

- Purchasing data and inventory records;
- Emission factors;

- Mass balance;
- Assumed a threshold was exceeded;
- Process recipes;
- Monitoring data;
- Production data; and/or
- Other.

During each site visit, surveyors reviewed information in the facility's supporting documentation to identify which approach, or which combination of approaches, was used to calculate thresholds. In cases where a facility's documentation was incomplete, site surveyors identified an approach that could reasonably have been used to estimate thresholds. Figure 4-1 summarizes the approaches that facilities in SIC Codes 33, 36, and 37 most commonly used to estimate thresholds for the chemicals that were reported to the TRI database. The figure indicates some notable trends:

- For all industries considered, facilities most often used purchasing data, inventory records, and process recipes to calculate thresholds for chemicals during RY 1996. Site surveys conducted following RYs 1987, 1988, 1994, and 1995 also found facilities frequently used these same approaches to calculate thresholds. The site surveyors generally agreed that facilities' use of purchasing data, inventory data, and process recipes was an appropriate approach for estimating thresholds, particularly for raw materials.

- Facilities in the primary metals industry (SIC Code 33) and the electronic and other electrical equipment industry (SIC Code 36) were twice as likely to assume that a threshold was exceeded than facilities in the transportation equipment industry (SIC Code 37). Previous analyses of site visit data found facilities that assume thresholds are exceeded are more likely to make incorrect threshold determinations than facilities that calculate actual quantities of chemicals manufactured, processed, and otherwise used. Sections 4.2 through 4.4 revisit the effect of assuming thresholds are exceeded on the quality of the TRI database.

4.2 Frequency of Incorrect Threshold Determinations

The following analyses indicate the frequency and type of incorrect threshold determinations made by facilities and project how erroneous determinations ultimately affect the quality of the TRI database. During site visits, surveyors used information provided by facility contacts to calculate thresholds for all EPCRA Section 313 chemicals that were manufactured, processed, or otherwise used. Based on these calculations and the required reporting threshold quantities, surveyors then listed the chemicals for which the facilities should have submitted EPCRA Section 313 reports. Errors in threshold determinations were identified by comparing the list of chemicals that the surveyor determined had exceeded thresholds to the list of chemicals for which facilities actually submitted EPCRA Section 313 reports. These comparisons yielded four possible outcomes:

- The facility submitted an EPCRA Section 313 report (i.e., either a Form R or a Form A) for a chemical that exceeded a threshold;
- The facility did not submit an EPCRA Section 313 report for a chemical that did not exceed a threshold;
- The facility submitted an EPCRA Section 313 report for a chemical that did not exceed a threshold; or
- The facility did not submit an EPCRA Section 313 report for a chemical that exceeded a threshold.

In the first two outcomes, the facilities correctly determined thresholds. The third outcome represents an incorrect threshold determination that causes facilities to unnecessarily submit Form Rs or Form As. The fourth outcome represents an incorrect threshold determination, and therefore causes facilities to fail to meet their statutory requirement of reporting environmental release and other waste management quantities to the TRI database. Important “right-to-know” information is then unavailable to the public.

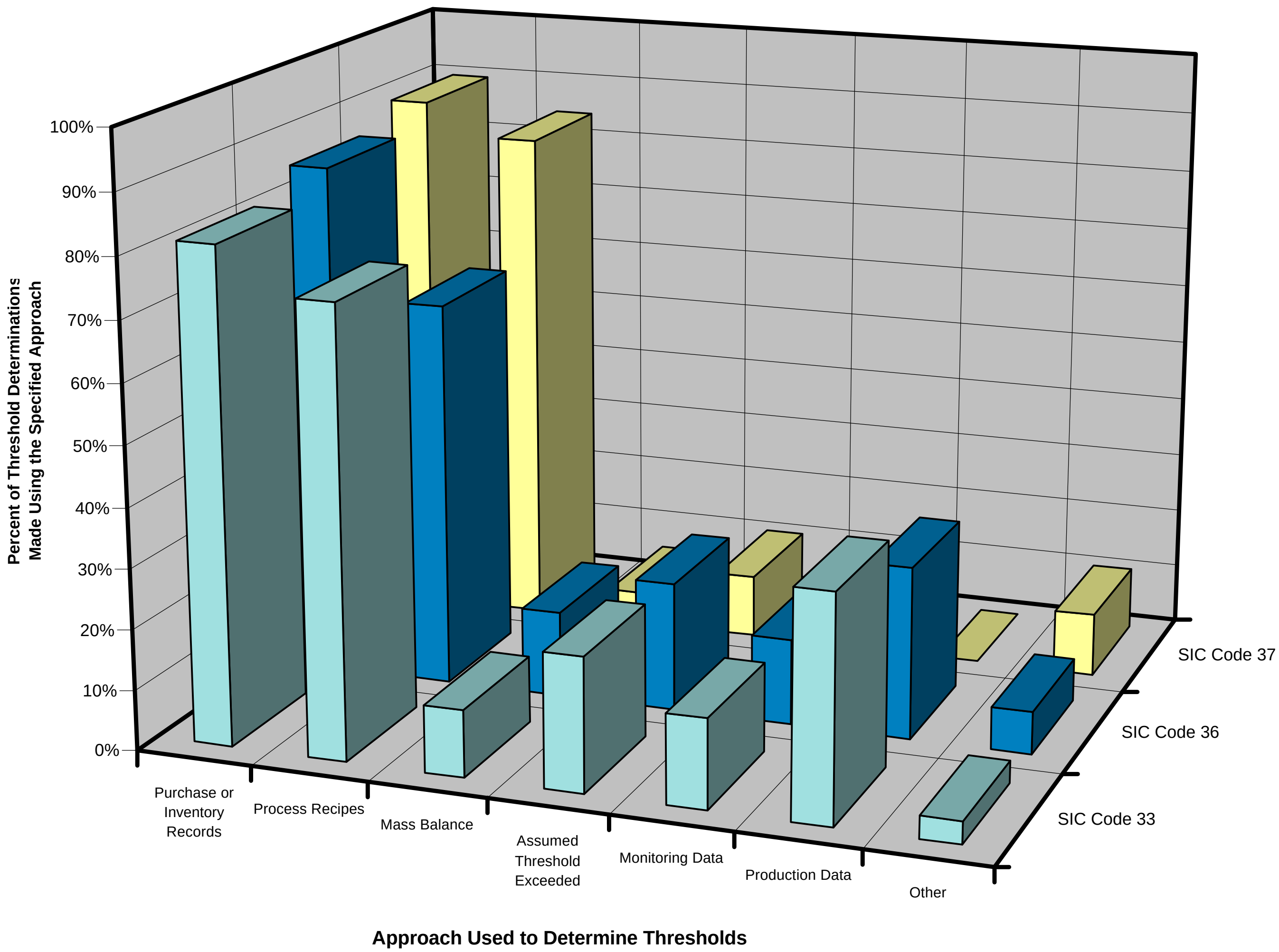


Figure 4-1. Approaches Used by Facilities to Make Threshold Determinations

Using the four possible outcomes, Tables 4-1, 4-2, and 4-3 and Figure 4-2 summarize the frequency that facilities made correct and incorrect threshold determinations during RY 1996. The tables and figure suggest several important observations:

- Over all SIC Codes considered, facilities determined thresholds correctly for over 90% of the EPCRA Section 313 chemicals used at their respective plants. According to a trend analysis of threshold determinations (see Table 4-3), the site survey project has found that the percentage of making correct threshold determinations has remained relatively constant over RYs 1987, 1988, 1994, 1995, and 1996.

- Facilities visited in the primary metals industry (SIC 33) had the highest frequency (8.3%) of incorrect threshold determinations, and most of the incorrect determinations were made for metals and metal compounds. The incorrect determinations were nearly evenly split between failing to submit EPCRA Section 313 reports for chemicals that exceeded thresholds (4.3% of errors) and submitting EPCRA Section 313 reports for chemicals that did not exceed thresholds (4.0% of errors). The impact of incorrect threshold determinations on the quality of the entire TRI database can be estimated by scaling the results of the current site visits up to the 6,603 EPCRA Section 313 reports that were submitted for RY 1996 for all facilities in SIC 33.[1] For example, the site surveyors concluded that 11 EPCRA Section 313 reports out of the 75 reports that were submitted by the selected facilities were actually for chemicals that did not exceed thresholds (see Table 4-1). This fact suggests that 970 of the 6,603 EPCRA Section 313 reports filed by facilities in SIC 33 for reporting year 1996 also were filed for chemicals that did not exceed thresholds. Similarly, the site surveyors concluded that the selected facilities should have submitted 12 EPCRA Section 313 reports in addition to the 75 that were reviewed, which suggests that facilities in SIC 33 should have submitted an additional 1,100 reports to TRI (see Table 4-2).

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[1] These extrapolations assume the reporting practices of the facilities visited are representative of the reporting practices of the industry as a whole.

Table 4-1

Accuracy of Threshold Determinations for Reporting Year 1996, by SIC Code

Threshold Determination Outcome		Number of EPCRA Section 313 Chemicals Reviewed, by SIC Code *(Percent of Total Chemicals Reviewed in the SIC Code Is Shown in Parentheses)*		
		SIC Code 33 (primary metals)	**SIC Code 36 (electronic equipment)**	**SIC Code 37 (transportation equipment)**
Total number of EPCRA Section 313 reports submitted by facilities that were visited		75	41	75
Correct threshold determinations	Facility submitted an EPCRA Section 313 report for a chemical that exceeded a threshold	64 *(23.2%)*	41 *(24.1%)*	68 *(18.2%)*
	Facility did not submit an EPCRA Section 313 report for a chemical that did not exceed a threshold	189 *(68.5%)*	122 *(71.8%)*	294 *(78.8%)*
Incorrect threshold determinations	Facility submitted an EPCRA Section 313 report for a chemical that did not exceed a threshold	11 *(4.0%)*	0 *(0.0%)*	7 *(1.9%)*
	Facility did not submit an EPCRA Section 313 report for a chemical that exceeded a threshold	12 *(4.3%)*	7 *(4.1%)*	4 *(1.1%)*

Table 4-2

Estimated Impact of Incorrect Threshold Determinations on the Number of EPCRA Section 313 Reports Submitted to EPA

SIC Code (industry)	Total number of EPCRA Section 313 reports filed by facilities in the industry for RY 1996	Estimated number of EPCRA Section 313 reports that were filed in RY 1996 for chemicals that did not exceed thresholds	Estimated number of additional EPCRA Section 313 reports that should have been filed in RY 1996
33 (Primary metals)	6,603	970	1,100
36 (Electronics equipment)	3,121	0	530
37 (Transportation equipment)	4,331	400	230

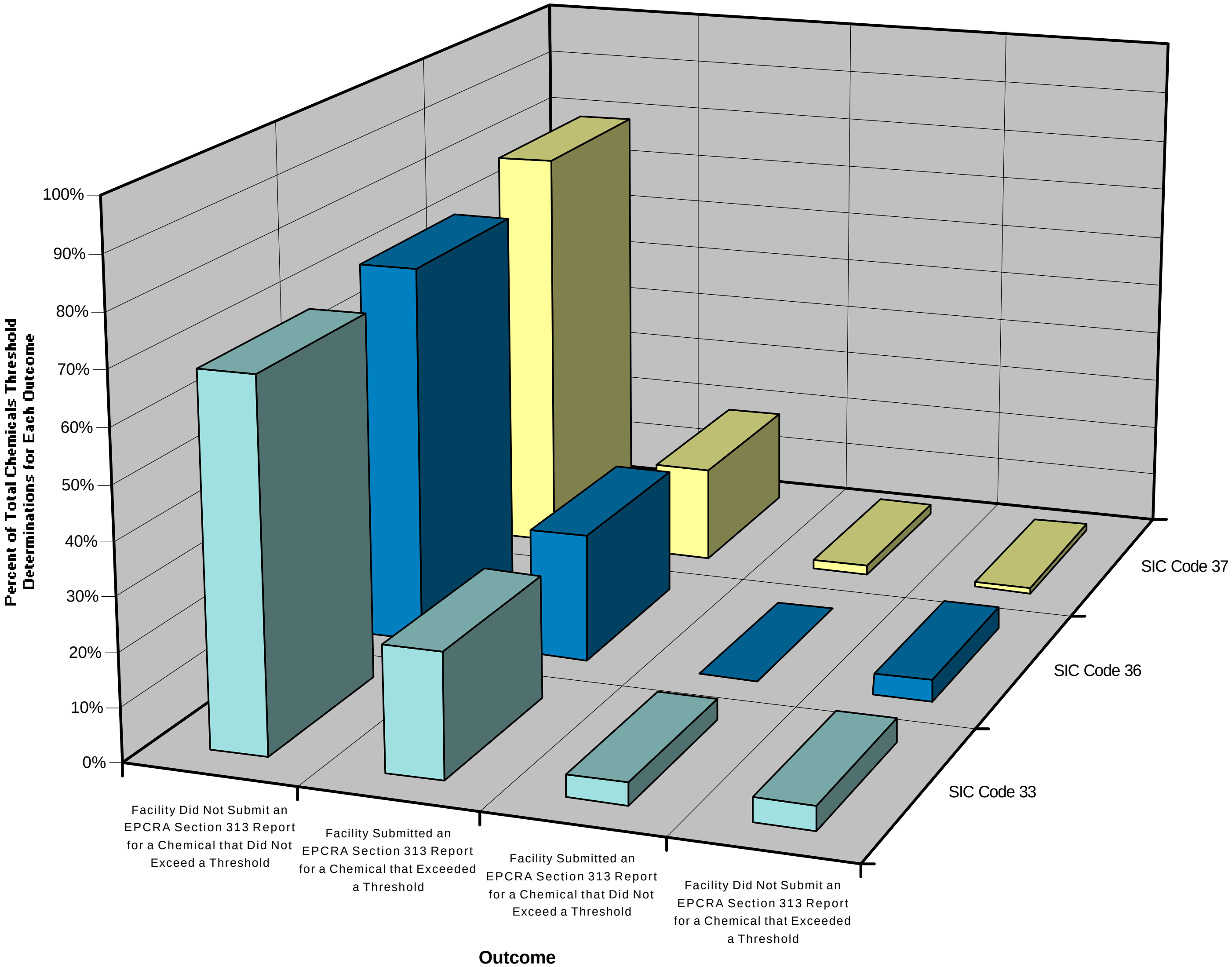
Note: Projections in this table were calculated from the data presented in Section 1 and assume that the reporting practices of the facilities visited during the site survey program are representative of the reporting practices of the facilities in the entire industry.

Table 4-3

Accuracy of Threshold Determinations by Reporting Year

Reporting Year	SIC Codes	Percent of Correct Threshold Determinations
1987	20-39	93.0%
1988	28, 291, 34-36	94.5%
1994	25, 281, 285, 30	93.3%
1995	26, 286	93.0%
1996	33, 36, 37	95.0%

Note: Refer to 1994 and 1995 Toxic Release Inventory Data Quality Report, USEPA, March 1998 for threshold determination data for reporting years 1987, 1988, 1994, and 1995.



Data for this figure can be found in Table 4-1.

Figure 4-2. Accuracy of Threshold Determinations by SIC Code

- Facilities visited in the electronics equipment industry (SIC Code 36) made incorrect threshold determinations less frequently than facilities in the primary metals industry (SIC Code 33); however, every incorrect threshold determination observed for facilities manufacturing electronics equipment resulted in the facilities failing to submit EPCRA Section 313 reports for chemicals that actually exceeded thresholds. Most of the incorrect threshold determinations were made for inorganic acids. Using the same extrapolation scheme presented in the previous bulleted item, the frequency of incorrect threshold determinations suggest that, on average, facilities in SIC Code 36 should have filed 530 EPCRA Section 313 reports in reporting year 1996, beyond the 3,121 reports actually filed (see Table 4-2).

- Facilities visited in the transportation equipment industry (SIC Code 37) made the fewest incorrect threshold determination errors of the three industries considered in the latest site survey program. The incorrect threshold determinations for this industry included metals, inorganic acids, and organic compounds. Of the 75 EPCRA Section 313 reports that site surveyors reviewed for facilities in this industry, seven were filed for chemicals that did not exceed thresholds. Further, site surveyors concluded that facilities did not submit EPCRA Section 313 reports for an additional four chemicals. Extrapolating the frequency of incorrect threshold determinations to the entire industry, the site survey results suggest that 400 of the 4,331 EPCRA Section 313 reports filed by facilities in SIC Code 37 for reporting year 1996 were for chemicals that did not exceed thresholds, and that an additional 230 reports should have been filed by facilities in this industry (see Table 4-2).

In summary, site surveyors found that in the industries surveyed, 95% of threshold determinations are made correctly, considering chemicals that both exceed and do not exceed thresholds. When only chemicals that actually exceed thresholds are considered, surveyors found that they were correctly reported as exceeding thresholds 88% of the time. Consistent with findings from previous years, the industry that had the fewest errors (SIC Code 37) was also the industry that was least likely to assume that thresholds were exceeded.

4.3 Reasons for Making Incorrect Threshold Determinations

This section summarizes why facilities made incorrect threshold determinations. During the site visits, surveyors classified the reasons for making each incorrect threshold determination into several general categories. The site surveyors identified the reasons for erroneous threshold calculations from discussions with facility personnel and from information in supporting documentation kept at the facility. The following discussion first explains why facilities failed to submit EPCRA Section 313 reports for chemicals that exceeded thresholds, then explains why facilities submitted reports for chemicals that did not exceed thresholds.

4.3.1 Reasons Why Facilities Failed to Submit EPCRA Section 313 Reports for Chemicals That Exceeded Thresholds

Table 4-4 summarizes the reasons why facilities failed to submit EPCRA Section 313 reports for chemicals that exceeded thresholds during reporting year 1996. As shown in the table, the most common reason why facilities did not identify chemicals used above threshold levels was because facilities simply overlooked the use of EPCRA Section 313 chemicals. Only two of the facilities visited made calculation errors that led to the erroneous conclusion that a chemical was not used at reportable levels. None of the facilities visited failed to submit reports due to misclassifying a chemical activity between “manufacture,” “process,” or “otherwise use.” Other reasons for making incorrect threshold determinations all represent cases where facilities misinterpreted reporting exemptions or some other aspect of the reporting instructions. The following lists provide further insight into why facilities made incorrect threshold determinations, and indicate specific examples of errors documented during site visits:

Overlooking a chemical activity:

- To determine which chemicals exceed reporting thresholds, representatives from a steel mill calculated annual usage of metal alloys that are added to an electric arc furnace. The site surveyor noted that scrap metal used at the facility probably included other metal alloys that were not accounted for by the facility’s calculations. Analytical data for baghouse dusts and hazardous waste manifests suggested that the steel mill “processed” two additional metal compounds at levels exceeding 25,000 pounds.

- A manufacturer of transportation equipment was aware that the painting operations at the facility used glycol ethers but assumed that the usage could not possibly have exceeded threshold quantities. Review of purchasing data indicated that total annual usage was significantly greater than threshold amounts.

Table 4-4

Reasons Why Facilities Failed to Submit EPCRA Section 313 Reports for Chemicals That Exceeded Thresholds

Reason for not submitting a report for a chemical that exceeded a threshold	Number of chemicals that were not reported for the listed reason, by SIC Code *(percent of total shown in parentheses)*		
	SIC Code 33	**SIC Code 36**	**SIC Code 37**
Chemical was overlooked	10 *(83%)*	2 *(29%)*	3 *(75%)*
Chemical activity was misclassified	0 *(0%)*	0 *(0%)*	0 *(0%)*
Threshold quantity was miscalculated	0 *(0%)*	2 *(29%)*	0 *(0%)*
Other	2 *(17%)*	3 *(42%)*	1 *(25%)*
Total number of errors	12	7	4

Misinterpreting reporting instructions:

- A semiconductor manufacturer used hydrochloric acid and sulfuric acid in a series of enclosed spray-cleaning operations. The facility thought that the "acid aerosols" activity qualifier for these chemicals applied only to "acid aerosols" found in ambient air, and not enclosed equipment. The site surveyor noted that any hydrochloric or sulfuric acid in aerosol form—even aerosols present in enclosed spray-cleaning operations—should be counted towards thresholds.

- A metals processing facility was aware that it "processed" over 25,000 pounds of copper, but thought the copper wire was used only as an article. Noting that the facility's processes cause releases of some copper and change the original size of the wire, the site surveyor concluded that the article exemption did not apply.

4.3.2 Reasons Why Facilities Submitted EPCRA Section 313 Reports for Chemicals That Did Not Exceed Thresholds

Table 4-5 summarizes why facilities submitted EPCRA Section 313 reports for chemicals that did not exceed thresholds during reporting year 1996. Clearly, there were many different reasons why facilities made incorrect threshold determinations, with no single reason dominating the site survey results. (The "other" category included several different reasons for making incorrect threshold determinations.) The following list provides further insight into why facilities made incorrect threshold determinations and describes specific instances when site surveyors concluded that facilities submitted an EPCRA Section 313 report for a chemical that did not exceed a threshold:

- A metals processing facility calculated a 35,000-pound threshold for aluminum, but did not account for the “fume or dust” activity qualifier. The site surveyor noted that the facility actually “processed” less than 2,000 pounds of aluminum “fume or dust.”

- A facility submitted reports for all chemicals that were “manufactured,” “processed,” or “otherwise used” in quantities greater than 10,000 pounds per year, including for N,N-dimethylformamide, of which the facility “processed” approximately 15,000 pounds. The site surveyor noted that the 10,000 pound threshold applies only to chemicals that are “otherwise used” and that a 25,000 pound threshold applies to chemicals that are “manufactured” or “processed.” As a result, the surveyor concluded that the facility should not have reported for N,N-dimethylformamide.

Table 4-5

Reasons Why Facilities Submitted EPCRA Section 313 Reports for Chemicals That Did Not Exceed Thresholds

Reason for submitting a report for a chemical that did not exceed a threshold	Number of chemicals that were reported for the listed reason, by SIC Code *(percent of total shown in parentheses)*		
	SIC Code 33	**SIC Code 36**	**SIC Code 37**
Decided to report, even though aware that the chemical usage was below threshold levels	2 *(18%)*	NA	2 *(29%)*
Chemical activity misclassified	0 *(0%)*	NA	3 *(43%)*
Miscalculated the threshold quantity	1 *(9%)*	NA	0 *(0%)*
Chemical was delisted or modified	2 *(18%)*	NA	0 *(0%)*
Other	6 *(55%)*	NA	2 *(29%)*
Total number of errors	11	0	7

NA: Not applicable. None of the facilities in SIC 36 that were visited submitted an EPCRA Section 313 report for a chemical that did not exceed a threshold.

- A smelting facility kept a detailed materials inventory which indicated that the facility "processed" over 25,000 pounds of chromium and manganese. The site surveyor noticed that these metals were trace impurities in the facility's processes and probably were never present at concentrations exceeding *de minimis* levels. Based on a detailed review of Material Safety Data Sheets (MSDS)s, laboratory analytical data, and usage records, the site surveyor concluded that the *de minimis* exemption applied to the metals and that the facility should not have filed the corresponding EPCRA Section 313 reports.

- A facility submitted a Form R for phosphoric acid in every reporting year since 1987. In RY 1996, however, the facility noted that usage of phosphoric acid was below the corresponding thresholds. Fearing that not submitting a Form R for a chemical that was previously reported might somehow trigger an audit or enforcement response, the facility reported for phosphoric acid anyway.

As noted previously, Section 4.4 lists several recommendations to help facilities avoid making similar errors in future reporting years when determining which chemicals exceed thresholds.

4.3.3 Chemical Activity Classification

Because appropriate TRI reporting thresholds (e.g., 10,000 or 25,000 pounds) depend on how facilities use EPCRA Section 313 chemicals, it is important that facilities correctly classify chemical activities as either "manufacture," "process," or "otherwise use." Table 4-5 indicates that facilities in SIC Code 37 incorrectly submitted EPCRA Section 313 reports for three chemicals that exceeded thresholds as a result of misclassifying the chemical activities. To evaluate how accurately facilities classify chemicals, site surveyors documented activities for all EPCRA Section 313 chemicals based on information provided by facility contacts and on observations made during facility tours. Figure 4-3, which compares chemical activity classifications made by facilities to those made by site surveyors for RY 1996, suggests that the site surveyors generally agreed with the chemical activity classifications that facilities indicated on their EPCRA Section 313 reports. Site surveyors did not notice consistent reasons why facilities misclassified chemical usage.

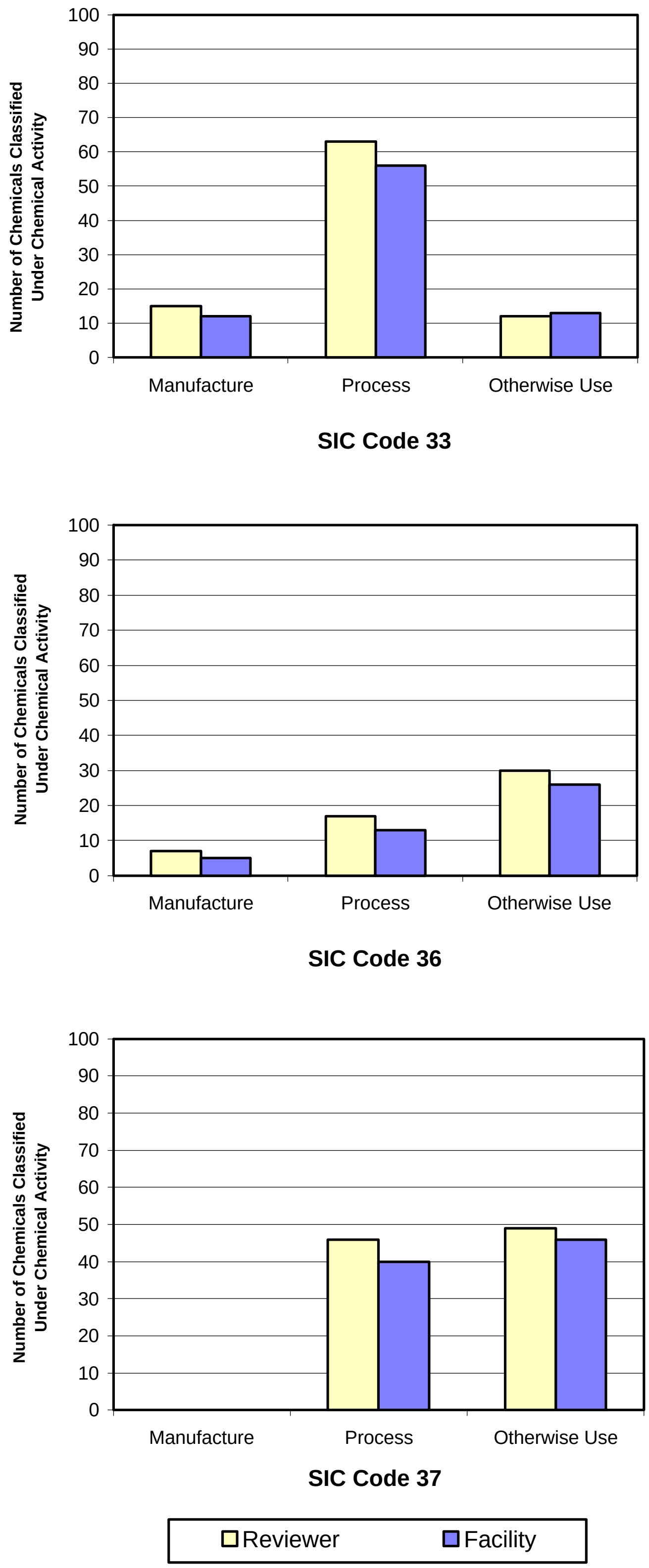


Figure 4-3. Comparison of Chemical Activity Classifications Made by Facilities to Those Made by Reviewers

4.3.4 Impact of Not Calculating Thresholds

An important factor to consider in the accuracy of threshold determinations is whether facilities actually calculated threshold levels for EPCRA Section 313 chemicals or whether they just assumed that thresholds were or were not exceeded. At each facility visited, site surveyors used feedback from facility contacts and data in supporting documentation to determine which method was adopted to make threshold determinations. For EPCRA Section 313 chemicals found to exceed reporting thresholds, Table 4-6 summarizes the frequency with which facilities in the selected industries actually calculated annual usages. Not surprisingly, facilities in the industries that calculated thresholds least often (SIC Code 33 and SIC Code 36) made more errors when determining thresholds than facilities in the industry that calculated thresholds more frequently (SIC Code 37). This observation, which is consistent with findings from site visits for reporting year 1994 and 1995[1], suggests that errors in threshold determinations may be significantly reduced if facilities actually calculate annual usages for EPCRA Section 313 chemicals, as opposed to assuming that chemicals are below or above reporting thresholds. Section 4.4 further discusses this issue.

4.3.5 Other Factors Correlating with the Frequency of Incorrect Threshold Determinations

As noted on the Survey Instrument (see Appendix A), site surveyors collected additional data from facilities on factors that are suspected to affect the quality of TRI reporting. These additional data include, but are not limited to, the amount of time facilities spend to prepare EPCRA Section 313 reports, the frequency with which facilities call the EPCRA hotline, and the title or position of the persons who completed a facility's EPCRA Section 313 reports. Comparing the frequency of making incorrect threshold determinations with these additional data revealed two interesting trends:

Table 4-6

Frequency with Which Facilities Calculated Thresholds for EPCRA Section 313 Chemicals, by SIC Code

SIC Code	Percent of Chemicals Reviewed by Site Surveyors for Which Facilities Calculated Thresholds
33	58.6%
36	81.3%
37	93.7%

Note: Data based on (1) chemicals that facilities submitted Form Rs or Form As and (2) chemicals that were "incorrectly not reported" (see Section 4.2 for definition).

- Industries in which "facility environmental staff" prepared EPCRA Section 313 reports tended to make the least amount of incorrect threshold determinations. More specifically, 68% of facilities in SIC Code 37 had "facility environmental staff" prepare EPCRA Section 313 reports, compared to 57 percent of facilities in SIC Code 36 and just 33% of facilities in SIC Code 33. (See Section 7 for further information on these distributions.)

- Industries in which the EPCRA Section 313 report preparers call the EPCRA hotline most frequently were found to make the least number of incorrect threshold determinations. More specifically, 68% of the facilities visited in SIC Code 37 called the EPCRA hotline, while 57% of the facilities visited in SIC Code 36 and only 48% of facilities visited in SIC Code 33 called the EPCRA hotline. (Again, see Section 7 for further information on these distributions.)

Although the previous associations between the type of staff completing EPCRA Section 313 reports and the frequency with which staff consult the EPCRA hotline appear to correlate with the accuracy of threshold determinations, further study is needed to determine whether this trend is statistically significant and applicable to other industries.

4.4 Lessons Learned

In summary, site surveyors found that facilities in the transportation equipment industry (SIC Code 37) determined thresholds more accurately than facilities in the primary metals and electronic equipment industries (SIC Codes 33 and 36). Although many factors likely contribute to this trend, the survey results suggest that facilities that calculate thresholds for EPCRA Section 313 chemicals make fewer incorrect threshold determinations than facilities that assume thresholds are exceeded.

Overall, facilities correctly calculated thresholds for 95% of the EPCRA Section 313 chemicals used at the selected industries. However, the frequency of incorrect threshold determinations suggests that the TRI database might not account for a significant quantity of chemicals used at reportable levels. More specifically, the site survey results suggest that for RY 1996, facilities correctly reported for 88% of the chemicals that actually exceeded thresholds.

Although the nature and extent of threshold determinations varies from one industry to the next, some general lessons can be learned from the mistakes identified by the site surveyors. Section 8 further discusses this issue.